ISIS

INDIVIDUALIZED SCIENCE INSTRUCTIONAL SYSTEM

Nerves in Action

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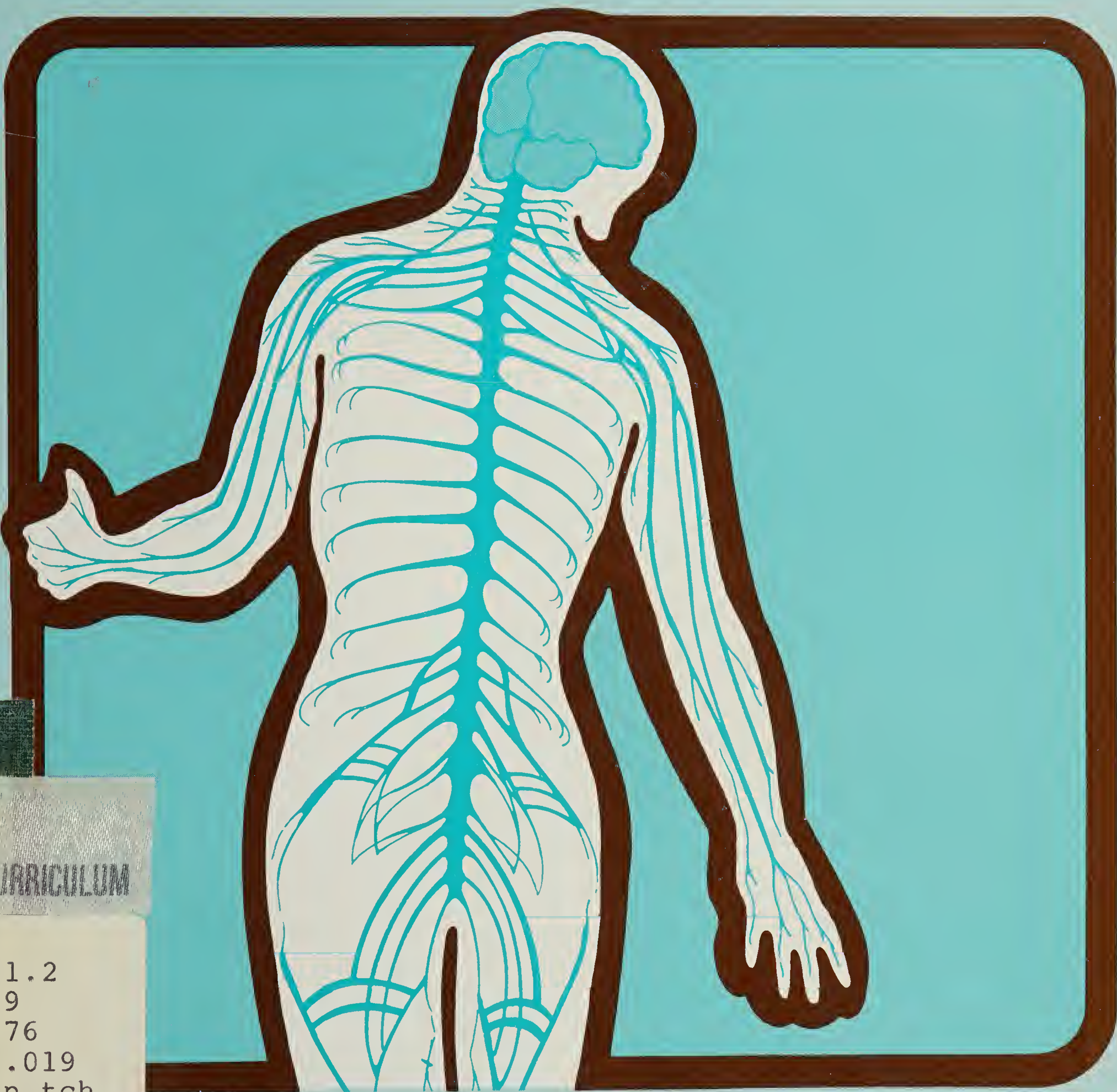

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Nerves in Action

ANNOTATED TEACHER'S EDITION

Ginn and Company

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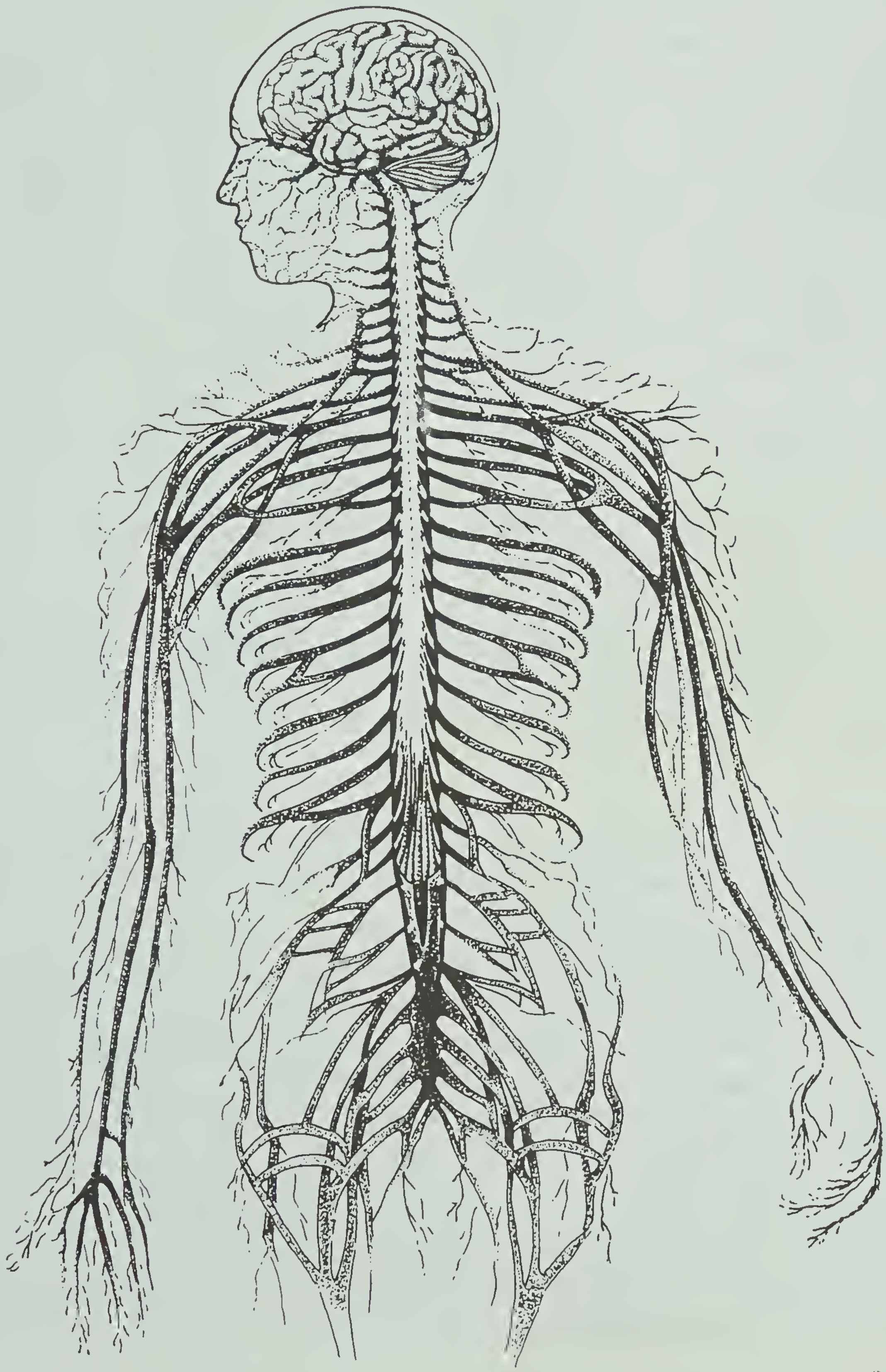
ANNOTATED TEACHER'S EDITION

CONTENTS	ATE PAGE



OVERVIEW

Nerves in Action introduces students to the principal parts of the human nervous system and discusses how each part functions in controlling the body's actions. The sense organs, the transmission of nerve impulses, and the mechanics of responses are explored. In addition, students study the effects of drugs, injuries, and diseases on the nervous system, and they compare the nervous systems of several organisms.

ORGANIZATION

Nerves in Action contains ten core activities, three advanced activities, and four excursion activities. The first activity in each section is a planning activity and should be done before any of the other activities in that section.

In the core section, Activity 2 should be done right after Activity 1 and Activity 10 should be done last. Other core activities may be done in any order. The core activities focus on the names and functions of the principal parts of the nervous system, the different kinds of pathways that impulses take, the effects of injuries, diseases, and drugs upon nervous system functions, and the structures and functions of the five sense organs.

Advanced activities focus on the structure and function of neurons, including impulse transmission through them. Students also make a fairly detailed comparison of nervous systems in the protozoan, hydra, grasshopper, frog, and human being.

One excursion activity gives students a chance to observe neural structures and functions in the above organisms by examining live specimens, dissected specimens, and a model. (This can be done in conjunction with Activity 13, which is on the same subject.) In other excursions, students estimate their reaction times and learn how scientists discovered some of the sensory and motor areas of the brain.

MATERIALS AND EQUIPMENT

The following tables show the quantity and the frequency of use of each item used in each activity. The activities that require no materials are not listed in the tables.

It is important to collect and organize all the materials for each minicourse before the students begin any of the activities, since the students will be working simultaneously on different activities. Having all materials readily available allows students to do the activities in the order they choose. The amount of material you will need to make available will depend on the number of lab groups that will be doing each activity. As lab groups use the "skipping option" and as they scatter themselves throughout the activities, the total amount of materials needed at one time for each activity will decrease.

CONSUMABLE ITEMS	MINIMUM MATERIALS PER LAB GROUP† PER ACTIVITY		
	9	10	16
*Alcohol solution, ethyl (drop)		1	
*Bitter solution (drop)	2		
*Caffeine solution (drop)		1	
Cotton (cm^3)		1	1
Cotton swab	4		
*Culture, *Daphnia* (drop)		1	
*Culture, hydra (drop)			1
*Culture, pond-water (drop)			1
*Frog, dissected			1
*Grasshopper, dissected			1
*Meat, raw (mm^3)			5
*Nicotine solution (drop)		1	
*Salty solution (drop)	2		
*Sour solution (drop)	2		
Sugar (mg)	5		
*Sweet solution (drop)	2		
Towel, paper	2	2	
Water (cup)	1		

*See "Advance Preparations."
†A *lab group* is defined as one student, a pair of students, or any size group of students that you choose.

NONCONSUMABLE ITEMS	MINIMUM MATERIALS PER LAB GROUP† PER ACTIVITY									
	3	4	5	6	7	9	10	12	15	16
Blindfold	1	1								
Brick		1								
Chair, straight, with back					1					
Coverslip for microscope slide							1			1
*Diagnosis: Nerves in Action Game				1						
Eraser, chalkboard		1								
Lens, hand			1							
*Mallet, rubber					1					
Medicine dropper							1			1
*Metre stick									1	
Microscope, compound							1			1
Microscope slide							1			1
Microscope slide, depression										1
Mirror, hand						1				
*Model, human body, with brain										1
Model, human ear (optional)						1				
Model, human eye (optional)			1							

*See "Advance Preparations."
†A *lab group* is defined as one student, a pair of students, or any size group of students that you choose.

NONCONSUMABLE ITEMS	MINIMUM MATERIALS PER LAB GROUP† PER ACTIVITY									
	3	4	5	6	7	9	10	12	15	16
Pan, dissecting										1
Pencil	1	1								
Penlight			1							
Pin, straight										10
Probe, dissecting										1
*Reaction-time ruler									1	
Spatula or wood splint						1				
Table, sturdy					1					
*Touch Tester Set made from	1									
cork	6									
pins, round-headed straight	11									
Watch or clock with second hand						1	1			
Resource Unit 1							1			
Resource Unit 3							1			1
Resource Unit 13			1							
Resource Unit 24								1		

*See "Advance Preparations."

†A *lab group* is defined as one student, a pair of students, or any size group of students that you choose.

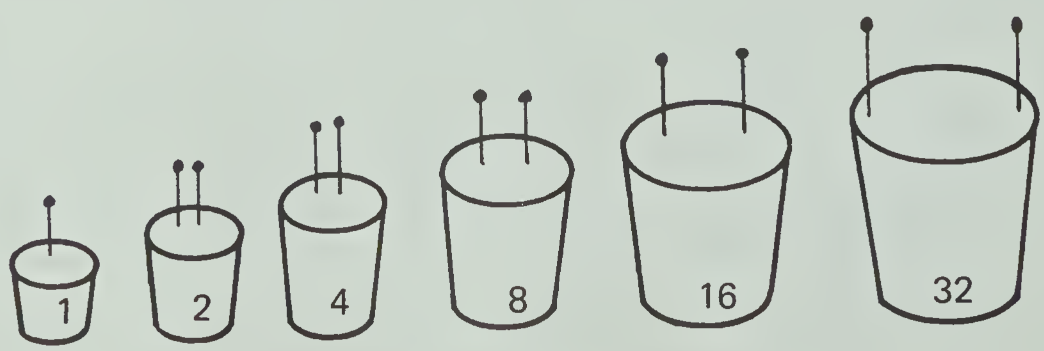
ADVANCE PREPARATIONS

Activity 3

The Touch Tester Set, which can be stored in a labeled cardboard box, is easily assembled as follows.

Obtain six corks ranging in size from ¾" to 1¼" in diameter. At least one should be 1¼" and one other 1". Obtain 11 round-headed straight pins.

Label the corks as follows: *1, 2, 4, 8, 16,* (1" diameter), *32* (1¼" diameter). Into the center of Cork 1, insert a single pin so that the head protrudes about 15 mm (5/8"). Into Cork 2, insert two pins with shafts parallel and exactly 2 mm apart. Into Cork 4, insert two pins with parallel shafts exactly 4 mm apart, and so on. (See the diagram below.) The number on the label indicates the distance between the two contact points.



An alternative is to use two toothpicks, two rubber bands, and a metric ruler. The student then moves the toothpicks farther apart, testing until two points are felt.

Activity 6

The nervous system "conditions" required for Activity 6 are those deemed important by the ISIS medical consultant. However, a list of ten conditions may be too challenging for some students. You might, therefore, want to consider decreasing the number of conditions to be learned. Meningitis, Parkinson's disease, and encephalitis might be dropped. Encourage students to have plenty of practice with the game before taking the test on Activity 6.

Activity 7

The best rubber mallet for these tests is the kind physicians use for the same purpose. You can prepare an adequate substitute by inserting a pencil into a one-hole stopper. Or you can use a ring stand rod, if you cover the end (10 cm to 15 cm) with rubber tubing.

CAUTION	Do not allow students to use the edge of a ruler or a book. A ruler is too light and sharp; a book is too blunt.

Activity 9

Place the solutions in dropping bottles as follows.

Salty solution: 10% sodium chloride (10 g NaCl + 90 ml water)

Sweet solution: 5% sugar (5 g sugar + 95 ml water)

Sour solution: vinegar solution (33 ml vinegar + 66 ml water; or 1% acetic acid)

Bitter solution: aspirin solution (4 aspirin in 100 ml water) or quinine sulfate solution (0.2%). (Check the taste.) You will want to find out whether any of your students are sensitive or allergic to aspirin.

Activity 10

A *Daphnia* culture is preferable in this activity. Since it may take some time to locate a supply, you should start looking right away. *Daphnia* are available from many commercial supply houses and some pet or tropical-fish stores. Make arrangements for keeping the *Daphnia*. Biological source books usually list several methods of care, as do commercial suppliers. For just a couple of days' use, the easiest method is to prepare dechlorinated tap water (letting it stand overnight) and add nonfilamentous algae from the walls of an aquarium and a small amount of hard-boiled egg yolk crushed in water. About fifty *Daphnia* per litre of liquid will survive quite well in this mixture.

If you cannot obtain *Daphnia*, it is possible to perform the experiment with a goldfish or a small frog. Wrap the goldfish in wet gauze except for the tail. Place it in a petri dish with a small amount of water and have the students observe the blood circulation in the webbing of its tail under both low- and high-power objectives of the microscope.

A frog can be anesthetized by putting it in a solution of chloretone for 15 to 30 minutes. Add one part of 0.5% chloretone in water to four parts of Ringer's solution. (See any biological source book for ways to prepare Ringer's solution, or you may be able to obtain some from a local hospital.) Then position the frog on the stage of the microscope so that students can observe the blood circulation in the webbing of its foot. The stimulant and depressant solutions can be dropped directly on either the webbing of the frog's foot or the tail of the goldfish.

Stimulant and Depressant Solutions

A 20% ethyl alcohol solution is recommended. Do not use denatured alcohol. If absolute alcohol is unavailable, 80-proof vodka can be diluted half strength. Place it in a dropping bottle labeled *Ethyl Alcohol Solution*.

For the caffeine solution, a weak-to-moderate coffee or tea solution may be prepared in the usual fashion. An alternative is to dissolve a caffeine tablet in 100 ml of water. Certain cola drinks may also be used, if allowed to go completely "flat" beforehand. Place the solution in a dropping bottle labeled *Caffeine Solution*.

A nicotine solution may be made by soaking the tobacco from one cigarette overnight in distilled water. Strain the tobacco from the solution the following morning and pour it into a dropping bottle labeled *Nicotine Solution*.

Activity 15

Prepare a reaction-time ruler by cutting out the calibrated strips on the Reaction-Time Ruler Pattern provided on page ATE 14 and joining them as indicated. Use cardboard or a metre stick as backing.

Activity 16

This activity requires all of the following: a living pond-water culture, a hydra culture, a human body model (with removable parts), and dissected specimens of a grasshopper and a frog. Since this is an excursion activity, one of each of the latter three should be adequate. If your school already has preserved dissections, these will probably be adequate, assuming the nervous systems (brain and nerve cord) are exposed and undamaged.

If you must prepare your own dissections and collect your own pond-water and hydra cultures, you may find it helpful to consult the several good references listed in the "References" in the ATE front matter. *A Sourcebook for the Biological Sciences* by Morholt, Brandwein, and Joseph is especially valuable.

Since the dissected specimens will be reused, special care must be taken. If possible, have all students use the same specimens on the same day. If necessary, a specimen can be covered with plastic wrap and kept in the refrigerator overnight. But the best procedure is to return the specimen to the preservative solution overnight and pin it to the dissection pan again just before the next class period.

BACKGROUND INFORMATION

Sensation

In core, the different types of nerve endings in the sense organs are discussed. Emphasis is on the pathways between the organs and the central nervous system. Little is said about the ways in which external stimuli generate nerve impulses in the various types of nerve endings. That information is supplied here.

The retina of the eye consists partly of photoreceptor neurons shaped like rods and cones. The rods contain rhodopsin (visual purple) and the cones contain iodopsin. Both chemicals are photosensitive, with rhodopsin being somewhat quicker to respond. Light breaks these chemicals down, and the energy released generates impulses in the associated neurons.

Sensory neurons in the organ of Corti in the inner ear are directly connected to sensory cells immersed in a fluid. When sound waves are transmitted through other parts of the ear to this fluid, the hairs move. The resulting stress initiates impulses in the dendrites of the sensory neurons.

A similar arrangement exists in the saccule. Changes in head position affect the fluid, which in turn pulls the hairs and stimulates the dendrites. The impulses reach the brain as messages of balance.

Impulse initiation in sensory neurons in the upper part of the nasal cavity (sense of smell) and in the tongue (sense of taste) is less well understood. Supposedly, the ions or molecules in compounds differentially affect different types of sensory neurons to produce different sensations of taste and smell.

The skin senses depend upon at least seven different types of nerve endings. For one type, the dendrites are wrapped around the roots of the body hairs; impulses are generated when the hair moves. Other types respond to pressure, pain, touch, and heat and cold.

Proprioceptors are structures in which neural dendrites are coiled around structures in muscles and tendons. Stretching produces impulses in the associated neurons. The structure within a muscle is called a *neuromuscular spindle.*

Finally, interoceptive receptors are neurons with endings in many of the internal organs. Usually, movement of some sort in the organ initiates impulses in the neuron.

Effects of Marijuana on the Human Body

Much controversy has accompanied research findings related to the effects of marijuana. Apparently the effects can vary considerably, depending on dosage, method of intake, and past drug experience, as well as on various psychological factors. For a summary of recent findings, see *Marihuana and Health* (6th Annual Report to the U.S. Congress).

Impulse Transmission in Neurons

In Activity 12, a simplified account of the transmission of nerve impulses is given. Actually, the process is more complicated, and the vocabulary used to describe it assumes a certain background knowledge.

The membrane of the resting neuron is said to be polarized because the inside is electrically negative compared to the outside. The negative charges are held on particles too large to leave the cell, but the positively charged K^+ ions can leave the inside of the cell partway. They are held near the outside surface by the attraction of the negative ions inside the cell.

When a stimulus is applied, the cell membrane becomes more permeable to Na^+ ions. (The degree of permeability depends on the strength of the stimulus.) The ions start diffusing into the cell, leaving a predominance of negative ions outside the membrane at that point and a predominance of positive ions inside.

An electrical current is set up between those negative ions and the Na^+ ions immediately ahead on the outside of the cell membrane. This current, acting as a stimulus, causes the cell membrane immediately ahead to become permeable to Na^+ ions, and the same process repeats here and all along the neuron.

Meanwhile, when the Na^+ ions diffuse inward, the cell membrane becomes more permeable to K^+ ions, which are inside the cell. These begin to diffuse outward, bringing a return of normal polarity.

As a result of this activity, there is more Na^+ now on the inside and more K^+ now on the outside. Gradually, the "sodium pump" replaces the K^+ ions with Na^+ ions on the outside of the membrane, and returns the K^+ ions to the inside of the cell. That part of the cell is then fully recovered.

Parts of the Brain

In the student booklet, only three parts of the brain are mentioned: the cerebrum, the cerebellum, and the brain stem. There are actually six major parts of the brain. Three of these are often collectively referred to as the brain stem: the pons, the midbrain, and the medulla oblongata. The other major parts are the cerebrum, the cerebellum, and the diencephalon.

The cerebrum is the center of all higher mental functions, including personality and intelligence. It is responsible for most conscious sensations and motor functions, as well as for some autonomic ones. Memory and emotion also seem to be centered there.

The diencephalon includes many autonomic centers and some conscious sensory centers. It functions in reward sensations (pleasantness or unpleasantness) and also serves as a relay between the cerebrum and some lower autonomic centers.

The cerebellum is involved in muscle coordination and equilibrium.

The medulla oblongata is a relay point where a crossing-over of nerve tracts occurs. It is also the control center for the breathing and heartbeat reflexes. Injury to the medulla often results in death.

The pons and midbrain serve as centers for certain reflexes involving cranial nerves — peripheral nerves that enter the brain directly rather than by way of the spinal cord.

The Autonomic Nervous System

The vagus is a huge autonomic nerve originating in the brain stem. Together with several other cranial and spinal nerves, it comprises the parasympathetic part of the autonomic system. The autonomic nerve trunks along the spinal cord are the sympathetic part.

The sympathetic system acts to strengthen the ability to adapt to changes in the outside environment, to secure food, and for protection — expending energy. The parasympathetic generally acts oppositely, restoring and conserving energy by inhibiting or slowing down actions of organ systems. The table below lists some of the actions of the autonomic system on various organs.

SELECTED ACTIONS OF AUTONOMIC SYSTEM		
Organ	Sympathetic	Parasympathetic
Adrenal gland	stimulates	no action
Bladder	inhibits	stimulates
Blood vessels	mostly constricts	mostly dilates
Bronchi	dilates	constricts
Heart	stimulates	inhibits
Intestinal tract	inhibits	stimulates
Iris of eye	dilates	constricts
Salivary glands	inhibits	stimulates
Sweat glands	stimulates	no action

EVALUATION SUGGESTIONS

In addition to the *Minicourse Test*, answers to which are provided with the test, you may want to use the following essay questions.

Essay Questions

Three essay questions are included here with model answers for your convenience. The questions relate to material found in core activities.

1. How does the human brain receive information from the environment on which to base conscious decisions?

Answer: When nerve endings in the sense organs are stimulated, messages pass through the extensions of sensory neurons (in peripheral nerves) to the spinal cord, where they are passed on to interneurons. The messages travel through interneurons to the cerebrum of the brain, where decisions are made.

2. In what ways (accidentally or with purpose) can the normal action of the nervous system be affected? What are the effects?

Answer: If some part of the brain is injured or becomes diseased, sensation or control of muscles may be lost. If the spinal cord or a nerve is cut, an impulse can't travel through it, and the person may become partially paralyzed or lose sensation in certain body parts.

Drugs can affect the nervous system by stimulating or depressing nerve message transmission or by interfering with the message in some way.

3. Describe and give an example of each of three types of nervous system reflexes.

Answer:

A. Muscle stretch reflexes. These reflexes occur when sensory nerve endings around muscle spindles are stimulated, causing muscle contraction. The knee-jerk reflex is this type.

B. External reflexes. These reflexes occur when sensory nerve endings in the sense organs are stimulated. Moving a hand when something hot is touched is this type.

C. Autonomic reflexes. These reflexes occur when the autonomic center in the brain causes changes in body processes. An example is sweating when the body is hot.

REFERENCES

Anthony, Catherine Parker, and Kolthoff, Norma Jane. *Textbook of Anatomy and Physiology*. St. Louis: The C.V. Mosby Co., 1978.

This is a college-level text, recommended for use by the teacher.

Asimov, Isaac. *The Human Brain: Its Capacities and Functions.* New York: New American Library, 1963.
This paperback (Mentor ME1558) is a clear and fascinating description of how the brain organizes and controls the functioning of the individual.

Easton, D.M. *Mechanisms of Body Functions.* 2nd ed. New York: Prentice-Hall, 1973.
This is a good college-level text, recommended for use by the teacher.

Grollman, Sigmund. *The Human Body: Its Structure and Physiology.* 4th ed. New York: Macmillan Publishing Co., Inc., 1978.
This text is appropriate for the teacher.

Hickman, Cleveland P. *Integrated Principles of Zoology.* 6th ed. St. Louis: The C.V. Mosby Co., 1979.

Klemm, W.R. *Science, the Brain, and our Future.* Indianapolis: Pegasus (Bobbs-Merrill Company), 1972.

Maclean, Paul D. "A Mind of Three Minds: Evolution of the Human Brain." *The Science Teacher* 45 (April 1978): 31-39.
The author traces the origins and functions of different parts of the brain and relates them to human behavior. It is an abstract discussion.

Pines, Maya. *The Brain Changers: Scientists and the New Mind Control.* New York: New American Library, 1973.
In this paperback (Signet J7885), the author discusses biofeedback, brain language, effects of drugs on the brain, and memory improvement. It is the winner of the 1974 American Psychological Foundation National Media Award.

Sagan, Carl. *The Dragons of Eden: Speculations on the Evolution of Human Intelligence.* New York: Ballantine Books, 1977.
This paperback (Ballantine 26031) is a history of the human brain from its beginnings to now. It is a provocative discussion of human intelligence.

Stevens, S.S.; Warshofsky, F.; and the Editors of *Life*. *Sound and Hearing.* rev. ed. New York: Time–Life, 1969.

Wang. J. "Breaking Out of the Pain Trap." *Psychology Today,* July 1977, pp. 78-86.
This is an excellent article for students interested in the mechanism of pain.

The following four works contain information about the actions of drugs on the nervous system and are suitable for reference by the teacher and students.

Brecher, E.M., and the editors of *Consumer Reports*. *Licit and Illicit Drugs: The Consumers Union Report on Narcotics, Stimulants, Depressants, Inhalants, Hallucinogens, and Marijuana — Including Caffeine, Nicotine and Alcohol.* Mount Vernon, New York: Consumers Union, 1972.
This comprehensive report covers the medical, legal, and social aspects of psychoactive drugs and their use.

Julien, R.M. *A Primer of Drug Action*. 2nd ed. San Francisco: W.H. Freeman and Company, 1978.

National Commission on Marijuana and Drug Abuse. *Drug Use in America: Problems in Perspective* (with appendix). Washington, D.C.: U.S. Government Printing Office, 1975.

National Institute on Drug Abuse. *Marihuana and Health.* Washington, D.C.: U.S. Government Printing Office, 1976.

The following are all helpful references for dissection techniques.

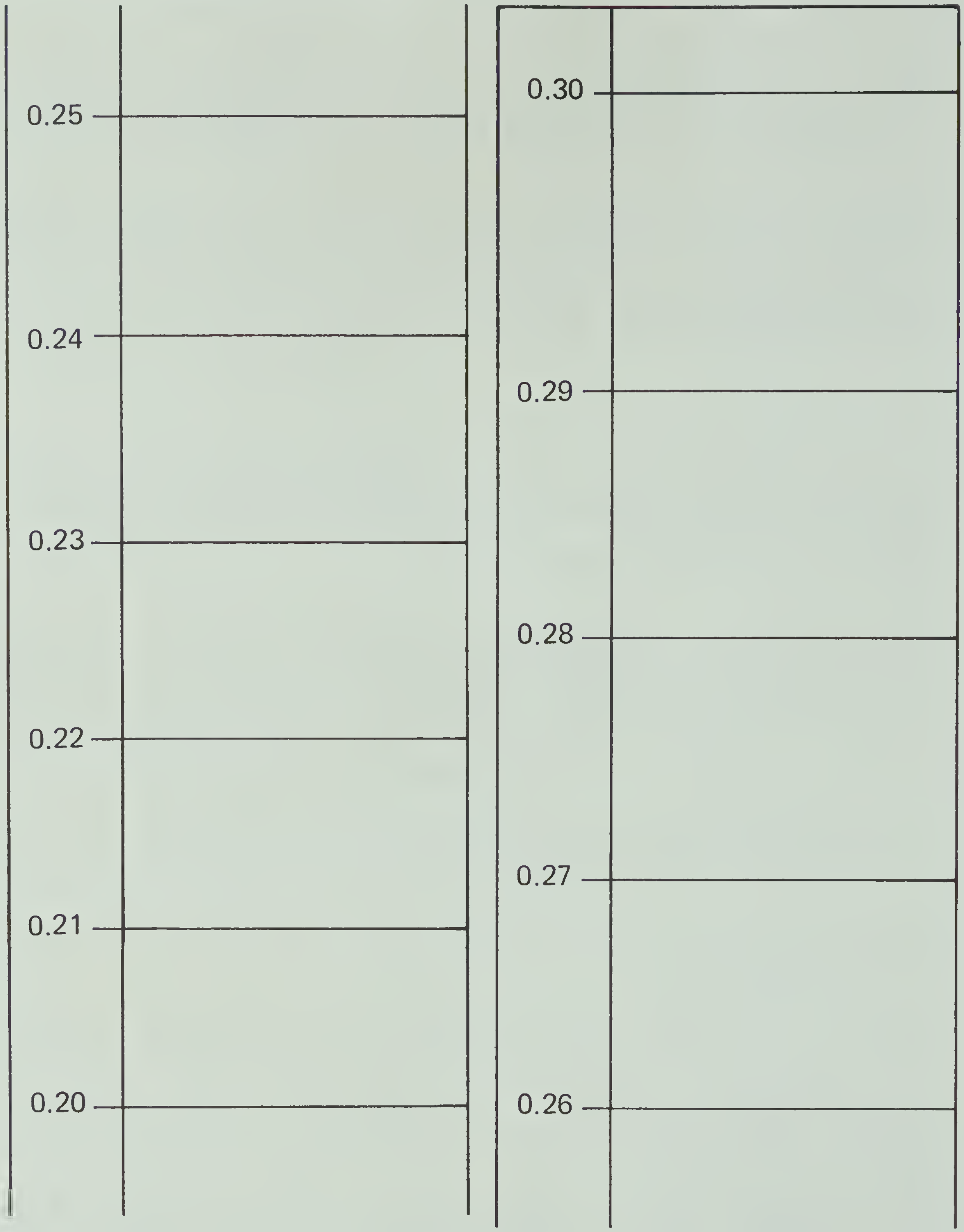
Behringer, Marjorie P. *Techniques and Materials in Biology*. New York: McGraw-Hill, Inc., 1973.

Morholt, E.; Brandwein, P.F.; and Joseph, A. *A Sourcebook for the Biological Sciences*. 2nd ed. New York: Harcourt, Brace, and World, Inc., 1966.

Otto, J.H.; Towle, A.; and Crider, E.H. *Biology Investigations.* New York: Holt, Rinehart and Winston, Inc., 1965.

Weisz, Paul B. *Laboratory Manual in the Science of Biology*. 4th ed. New York: McGraw-Hill, 1971.

PATTERN FOR REACTION-TIME RULER



Permission is granted ISIS users to reproduce Pattern for Reaction-Time Ruler in classroom quantities.

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In addition to the major effort by the ISIS permanent staff, writing conference participants, and author-consultants (listed on the inside of the back cover), the following contributed to this minicourse.

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FOREWORD

Evidence has been mounting that something is missing from secondary science teaching. More and more, students are rejecting science courses and turning to subjects that they consider to be more practical or significant. Numerous high school science teachers have concluded that what they are now teaching is appropriate for only a limited number of their students.

As their concern has mounted, many science teachers have tried to find instructional materials that encompass more appropriate content and that allow them to work individually with students who have different needs and talents. For the most part, this search has been frustrating because presently such materials are difficult, if not impossible, to find.

The Individualized Science Instructional System (ISIS) project was organized to produce an alternative for those teachers who are dissatisfied with current secondary science textbooks. Consequently, the content of the ISIS materials is unconventional as is the individualized teaching method that is built into them. In contrast with many current science texts which aim to "cover science," ISIS has tried to be selective and to limit our coverage to the topics that we judge will be most useful to today's students.

Obviously the needs and problems of individual schools and students vary widely. To accommodate the differences, ISIS decided against producing tightly structured, pre-sequenced textbooks. Instead, we are generating short, self-contained modules that cover a wide range of topics. The modules can be clustered into many types of courses, and we hope that teachers and administrators will utilize this flexibility to tailor-make curricula that are responsive to local needs and conditions.

ISIS is a cooperative effort involving many individuals and agencies. More than 75 scientists and educators have helped to generate the materials, and hundreds of teachers and thousands of students have been involved in the project's nationwide testing program. All of the ISIS endeavors have been supported by generous grants from the National Science Foundation. We hope that ISIS users will conclude that these large investments of time, money, and effort have been worthwhile.

Ernest Burkman
ISIS Project
Tallahassee, Florida

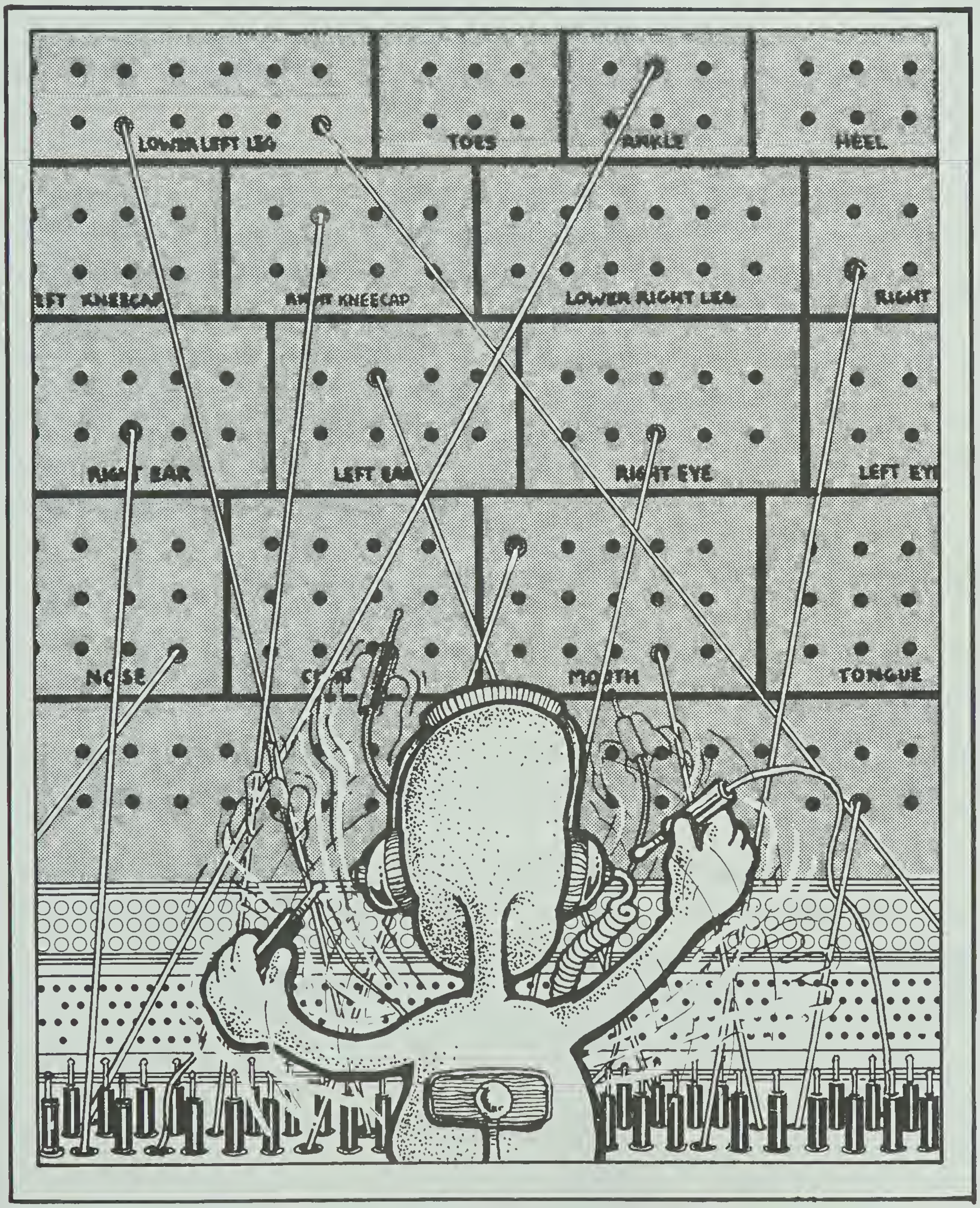
CONTENTS PAGE

WHAT'S IT ALL ABOUT?

The telephone network is probably the biggest and most complex system ever built. It's made up of many millions of telephones, wires, switches, relay stations, and even orbiting satellites.

But that system is simple compared to the communications system inside your body — your nervous system. It's more complex than thousands of telephone networks. And it handles a lot more than just sound messages.

In this minicourse, you'll learn how your nervous system is put together and how it works. You'll learn how some drugs that act on the nervous system affect your body. And you'll study several body reactions that the nervous system controls.



CORE

ACTIVITY 1: PLANNING

If you plan to do Activity 2, do it right after this planning activity. If you plan to do Activity 10, you should do it as the last of the core activities.

Activity 2 — Page 6

Objective 2-1: Identify the major parts of the human nervous system, and tell what each part does.

Sample Question: When you throw a ball, several sets of muscles work together. Which part of the brain coordinates these muscles?

A. The brain stem
B. The cerebellum
C. The cerebrum
D. The optic lobe

Objective 2-2: Identify three types of nerves, and describe what they do.

Sample Question: Sensory nerves

A. carry nerve messages to the spinal cord and brain.
B. are the nerve cells in sensory neurons.
C. carry nerve messages to muscles and organs.
D. carry nerve messages to sense organs.

Activity 3 — Page 10

Objective 3-1: Describe where sensory nerve endings are found and what they do.

Sample Question: Sensory nerve endings

A. respond to messages from the brain.
B. cause muscles to contract.
C. are found in the sense organs.
D. change stimuli into nerve messages.

Objective 3-2: Identify the stimuli sensed by the skin, and outline the path of nerve messages from the skin to the brain.

Sample Question: List these nervous system parts in the order in which a nerve message of touch is sent from the skin to the brain.

A. Sensory nerve
B. Cerebrum
C. Sensory nerve ending
D. Brain stem
E. Spinal cord

Activity 4 — Page 15

Objective 4-1: Trace the paths of motor nerve messages from the brain to voluntary muscles, and describe the roles of the cerebrum and cerebellum in sending motor nerve messages.

Sample Question: Motor nerve messages pass from the brain into the spinal cord and from there into

A. sensory nerve endings.
B. the cerebellum.
C. muscles.
D. motor nerves.

Objective 4-2: Explain how the brain controls the movement of body parts.

Sample Question: When a motor nerve message is sent from the brain to a paired set of muscles, what happens?

A. Both muscles contract.
B. Both muscles relax.
C. One muscle relaxes, and the other contracts.
D. Nothing happens unless a sense organ is involved.

Activity 5 — Page 20

Objective 5-1: **Identify the parts of the eye involved in the sense of sight, and tell what each part does.**

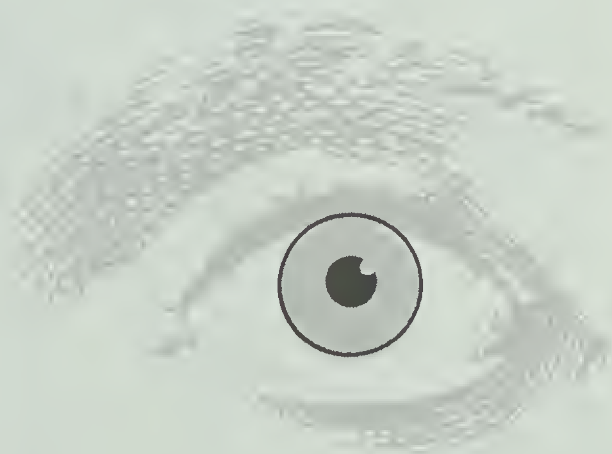
Sample Question: What is the function of the retina of the eye?

A. To focus light
B. To change light stimuli into nerve messages
C. To control the amount of light entering the eye
D. To carry sensory nerve messages to the brain

Objective 5-2: **Describe the iris reflex in terms of feedback.**

Sample Question: What stimulus provides feedback that is used to control the iris reflex?

A. The amount of light entering the eye
B. The size of the iris muscle
C. The number of times the eyelid blinks
D. The size of the retina



Activity 6 — Page 24

Objective 6-1: **Given the symptoms of a nervous system condition — brain injury, spinal-cord injury, brain tumor, encephalitis, epilepsy, Parkinson's disease, stroke, meningitis, multiple sclerosis, and cerebral palsy — identify the condition, and describe the causes, effects, and treatment of the condition.**

Sample Question: Match each nervous system condition with its cause.

Condition	Cause
A. Spinal-cord injury	1. virus (usually)
B. Stroke	2. bacteria (usually)
C. Brain tumor	3. accident
D. Meningitis	4. abnormal growth of brain cells
E. Encephalitis	5. stoppage of blood flow to area of the brain

Answers: **2-1.** B; **2-2.** A; **3-1.** C, D; **3-2.** C, A, E, D, B; **4-1.** D; **4-2.** C; **5-1.** B; **5-2.** A; **6-1.** A3, B5, C4, D2, E1

Activity 7 — Page 26

Objective 7-1: Define the term *reflex act*, and identify common examples of external and muscle-stretch reflex acts.

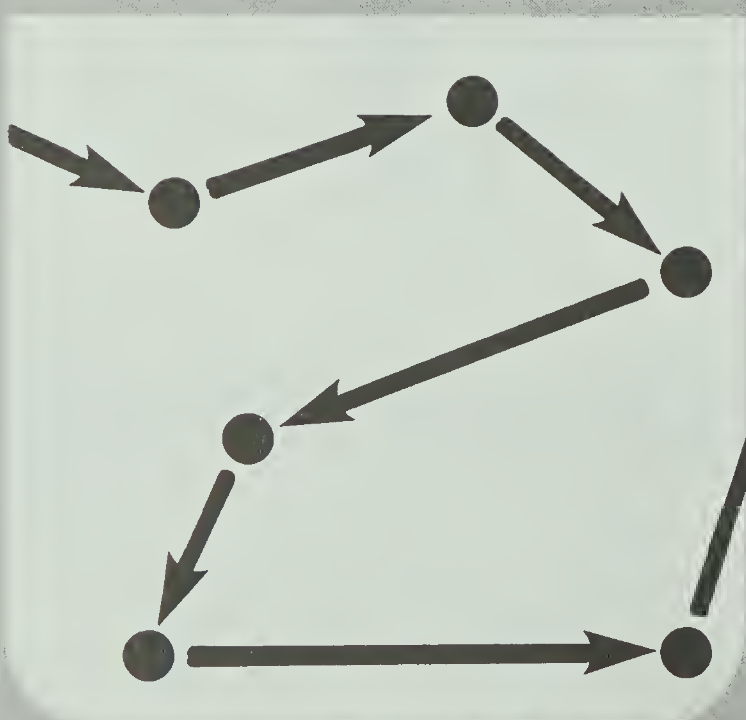
Sample Question: Which of the following is an example of a muscle-stretch reflex act?

A. Your hand jerks away when you touch a hot stove.
B. Your arm moves away when it is pinched by a friend.
C. You blink when a fly buzzes near your eye.
D. Your leg moves when it is tapped just below the kneecap.

Objective 7-2: Trace the nerve message pathway for muscle-stretch reflexes.

Sample Question: When a doctor taps the tendon below your kneecap, a muscle-stretch reflex occurs. List these nervous-system structures in the order that the reflex nerve messages pass through them.

A. Motor nerves
B. Sensory-nerve endings around spindles
C. Sensory nerves
D. Spinal cord



Activity 8 — Page 30

Objective 8-1: Define and give examples of autonomic reflexes.

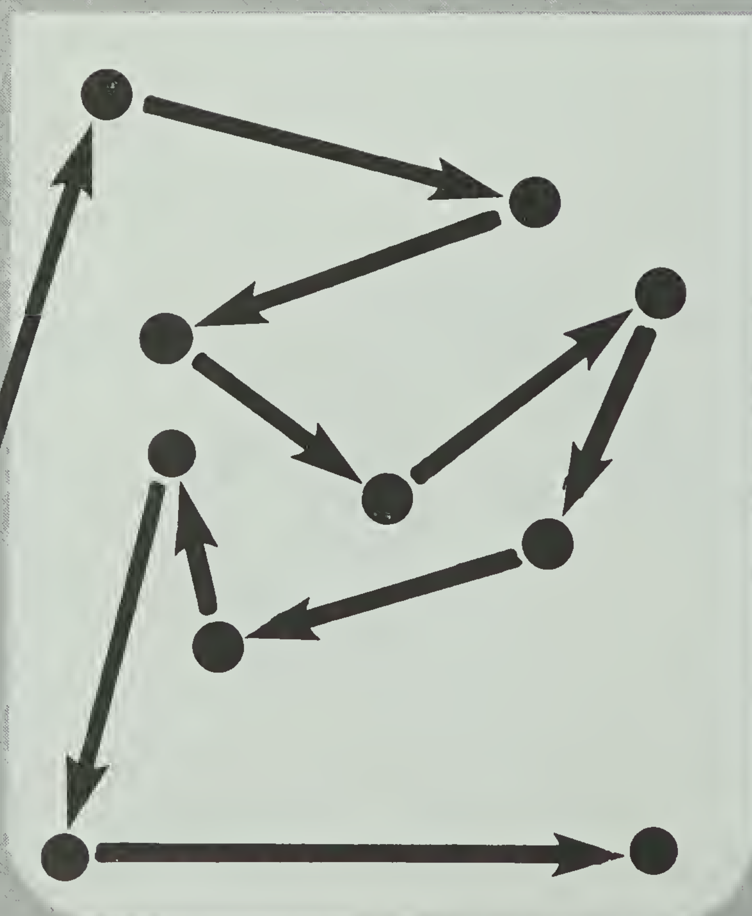
Sample Question: Which of the following are autonomic reflexes?

A. Knee jerk
B. Digesting food
C. Lifting weight
D. Sweating

Objective 8-2: Trace the pathway of a typical nerve message through the autonomic part of the nervous system, and describe the role that the brain plays in transmitting the message.

Sample Question: List these nervous system structures in the order in which a nerve message passes through them during an autonomic reflex.

A. Brain
B. Autonomic chain
C. Spinal cord
D. Autonomic motor nerves



Activity 9 — Page 34

Objective 9-1: Identify the main parts of the ear involved in the sense of hearing, and describe the role of each part.

Sample Question: Match each ear part with the role it plays in hearing.

Ear Part	Role
A. Eardrum	1. carries nerve messages to the brain stem
B. Organ of Corti	2. vibrates when sound enters the outer ear
C. Auditory nerve	3. transmits vibrations to the cochlea
	4. contains sensory cells

Objective 9-2: Describe how the senses of taste and smell work.

Sample Question: What four basic tastes are sensed by the taste buds?

A. Bitter
B. Fragrant
C. Salty
D. Sour
E. Sweet

Activity 10 — Page 41

Objective 10-1: Describe the actions on the human brain of the following psychoactive drugs: ethyl alcohol, heroin, amphetamines, cocaine, caffeine, nicotine, LSD, barbiturates, and marijuana.

Sample Question: Match the psychoactive drug with its action or actions on the human brain.

Drug	Action
A. Ethyl alcohol	1. depresses breathing centers in the brain stem
B. Marijuana	2. depresses alertness centers in the brain stem
C. Heroin	3. stimulates nerve cell activity in the cerebrum
D. Caffeine	4. unknown

Objective 10-2: Explain the results of drinking different amounts of alcohol in terms of alcohol's effects on parts of the brain.

Sample Question: Why do some people appear relaxed and talkative after one or two alcoholic drinks?

A. One or two drinks of alcohol stimulate centers in the cerebral cortex.
B. One or two drinks of alcohol depress motor-coordination centers in the brain stem.
C. One or two drinks of alcohol release centers in the cerebrum from control by the brain stem.
D. One or two drinks numb the cortex and activate the larynx.

Answers: **7-1.** D; **7-2.** B, C, D, A; **8-1.** B, D; **8-2.** A, C, B, D; **9-1.** A2, B4, C1; **9-2.** A, C, D, E; **10-1.** A1 and 2, B4, C1 and 2, D3; **10-2.** C

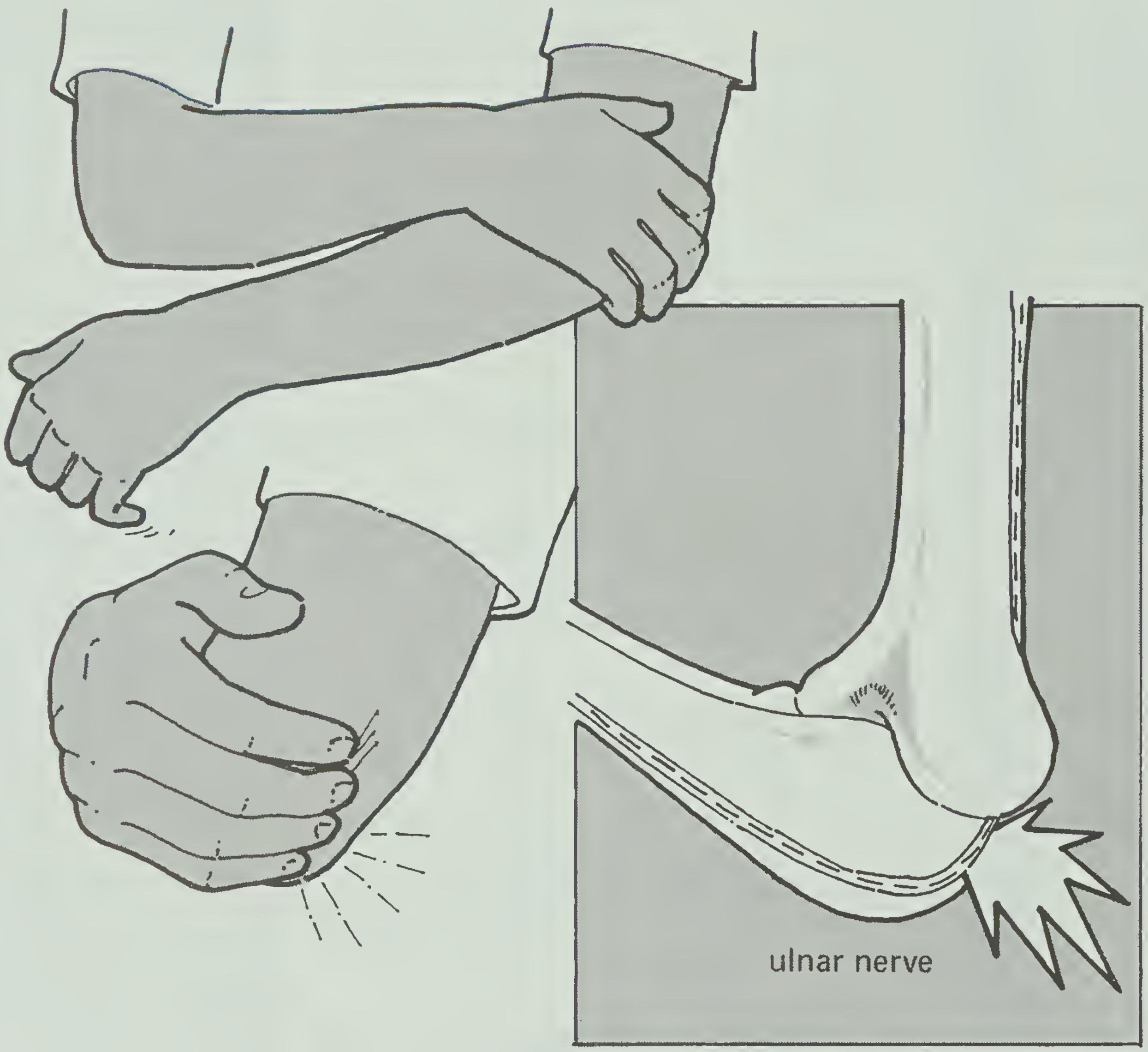
ACTIVITY EMPHASIS: The functions of the major components of the human nervous system — the cerebrum, cerebellum, brain stem, nerves, and spinal cord — are outlined.

MATERIALS PER STUDENT LAB GROUP: None

ACTIVITY 2: YOUR NERVOUS SYSTEM

Your nervous system is on the job twenty-four hours a day. Working nonstop, it carries messages, keeps track of what's going on in and around you, and controls your body's responses.

To get an idea of how the system works, try stimulating your own ulnar nerve. This nerve is sometimes called the *funny bone*. It comes close to the surface of the skin behind your elbow, which makes it fairly easy to stimulate.



A. Hold your left arm as shown.

B. With the fingers of your right hand, rub gently against the nerve. Do this until you feel a tingling in your left hand.

C. Stimulate the nerve more strongly by "plucking" it like a guitar string. Watch the fingers of your left hand. You should be able to cause one or more fingers to twitch.

When the ulnar nerve is stimulated, it sends out nerve messages. The messages go to your brain, where you sense a tingling in your fingers. Then the ulnar nerve carries messages from your brain to your fingers, causing your fingers to twitch. Messages that bring information from your senses are called *sensory* nerve messages. Messages that cause something to happen in your body are called *motor* nerve messages.

2-1. Sensory nerve messages and motor nerve messages

- 2-1. Name two kinds of nerve messages.

The "headquarters" of your nervous system is your brain. It's soft, gray colored, and wrinkled. In adults, it weighs just over a kilogram. Different parts of the brain do different things. Three of the main parts are shown and described in Figure 2-1 below.

brain

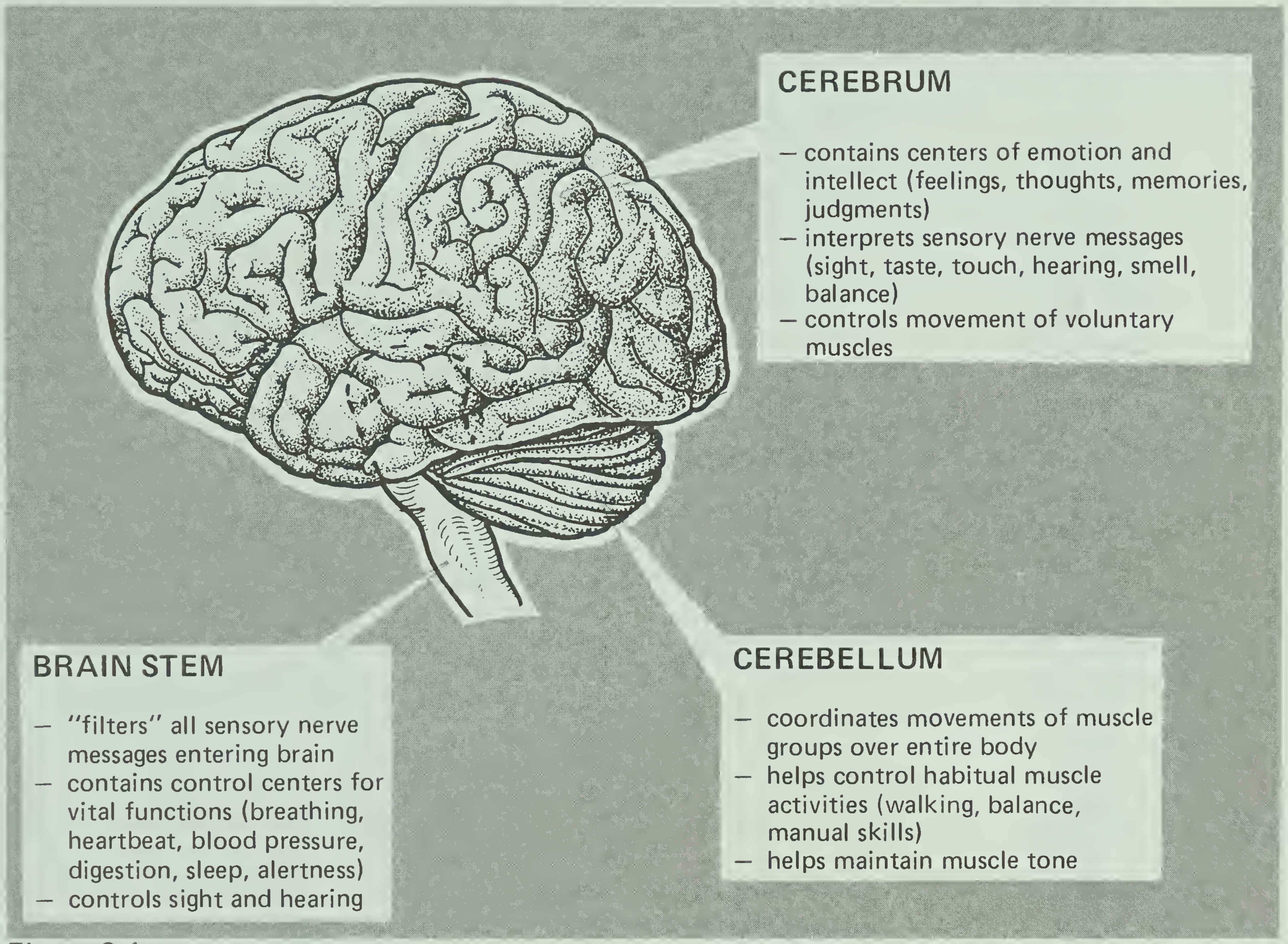


Figure 2-1

- 2-2. Where is the "sleep center" of the brain?

2-2. In the brain stem

- 2-3. When you throw a ball, what part of the brain is coordinating the muscles of your arm, hand, fingers, back, and legs?

2-3. The cerebellum

- 2-4. When you are learning science, which part of your brain is most involved?

2-4. The cerebrum

Some of your body organs are "plugged in" directly to the brain by cranial nerves. There are twelve pairs of these nerves. They connect parts of your brain with your eyes, ears, jaw, throat, and some organs in your chest and abdomen.

spinal cord

But the major route to and from your brain is your spinal cord. This cable of nerves is more than a centimetre thick and about 45 centimetres long.

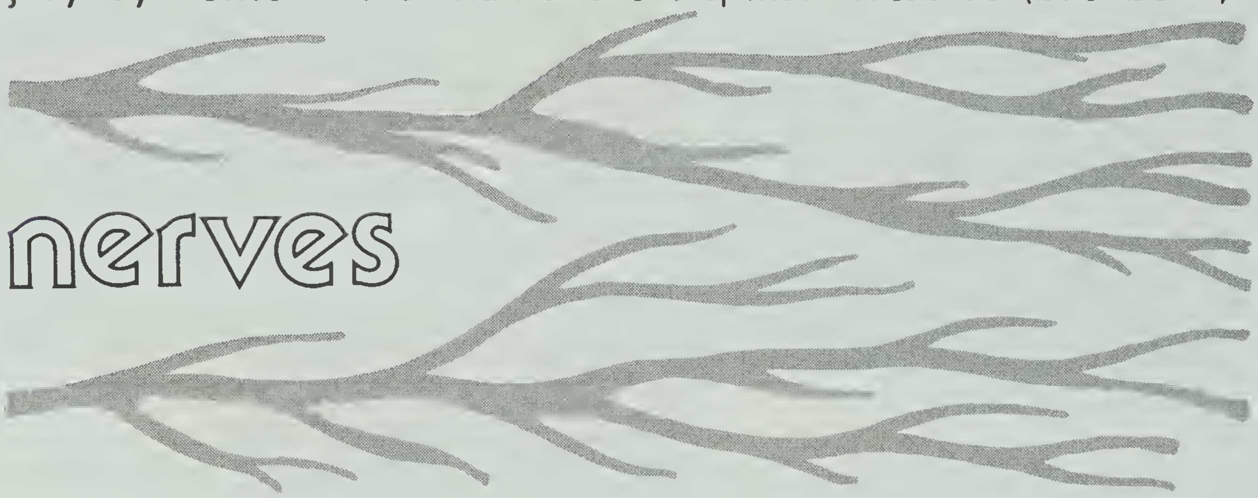
The spinal cord directly controls reflexes from your neck and lower body, but mainly it transmits sensory and motor nerve messages. It carries messages between various parts of your body, as well as to and from your brain. Thirty-one pairs of spinal nerves, branching and rebranching, connect your spinal cord with the rest of your body.

2-5. It carries messages to and from the brain and also between body parts.

2-6. 1C; 2B; 3A

● 2-5. How does the spinal cord function in carrying nerve messages?

The brain and spinal cord together make up what's called the *central nervous system* (CNS). The CNS is protected from injury by bones — the skull and the spinal vertebrae (backbone).



nerves

Outside the CNS is the peripheral [per-IF-er-ul] nervous system. It's made up of the spinal and cranial nerves and the nerves that connect with them. These nerves are the "wires" that carry the messages back and forth, reaching from brain and spinal cord to every part of your body. Nerves extend into every square centimetre of your skin, every bone, muscle, and blood vessel, and every internal organ.

Some nerves are one-way streets. Sensory nerves carry sensory messages from the sense organs to the CNS. Motor nerves carry motor messages from the CNS to the muscles. But some nerves, such as the ulnar nerve, carry messages both ways. They are called *mixed nerves.*

☆ 2-6. Match the type of nerve with its function.

Type of Nerve	Function
1. Mixed nerve	A. carries messages to brain and spinal cord
2. Motor nerve	B. carries messages from brain and spinal cord
3. Sensory nerve	C. carries messages to and from brain and spinal cord

Nerves consist of groups of cells. Each nerve cell has a cell body and one or more threadlike nerve fibers. The cell body helps provide energy for the cell. The nerve fibers carry nerve messages. Some fibers may be several feet long! Each nerve, such as the ulnar nerve in your arm, is a thick bundle of nerve fibers.

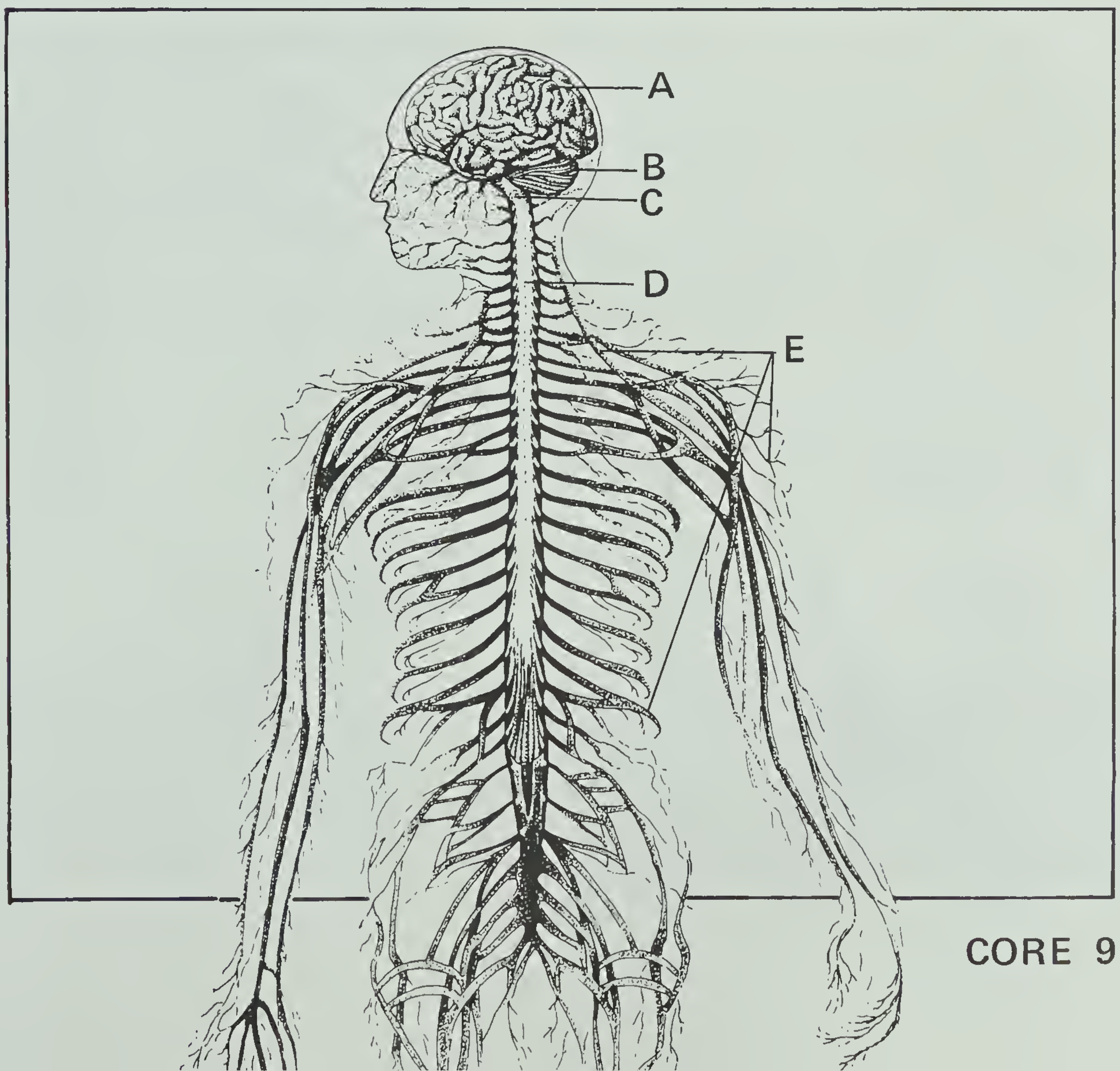
● 2-7. What are the two parts of a nerve cell?

2-7. The cell body and the nerve fibers

☆ 2-8. Identify the nervous system parts shown in the diagram below. Then match each nervous system part with its function or functions.

Part	Function
1. Brain stem	T. coordinating balance and movement
2. Cerebellum	U. filtering messages entering brain
3. Cerebrum	V. thinking and emotions
4. Nerves	W. carrying messages between central nervous system (brain and spinal cord) and rest of body
5. Spinal cord	X. carrying messages between some nerves and brain
	Y. controlling such processes as breathing and blood pressure
	Z. controlling movement of voluntary muscles

2-8. A3; V, Z
B2; T
C1; U, Y
D5; X
E4; W

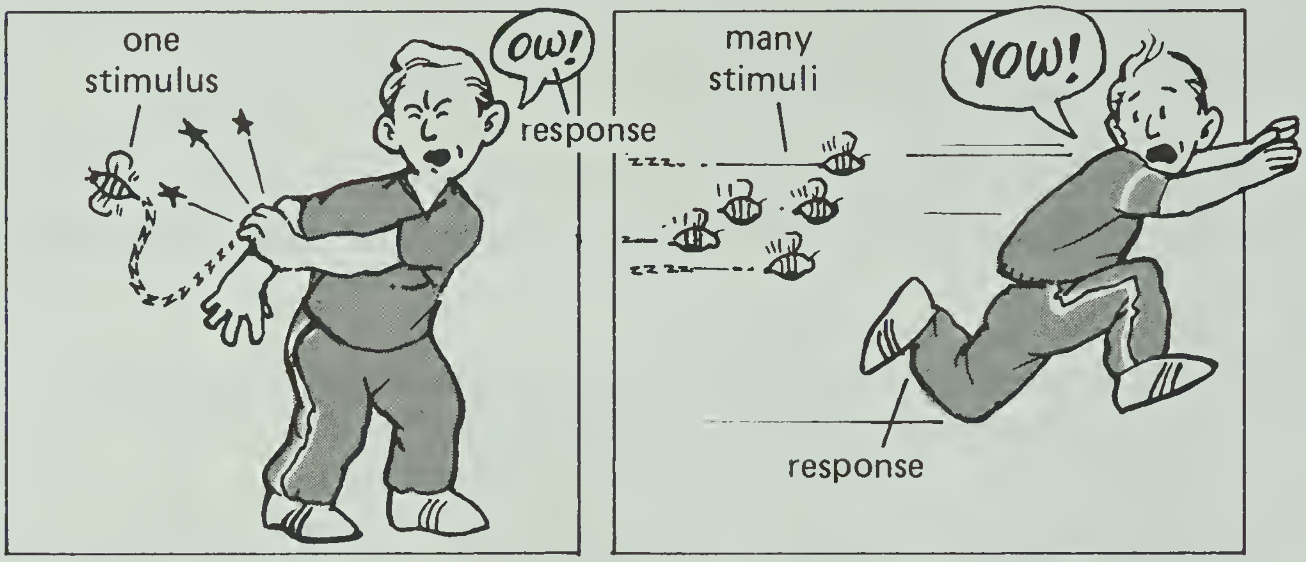


ACTIVITY EMPHASIS: Sensory nerve endings receive stimuli from the environment and translate them into nerve impulses. Impulses from the skin are sent through the spinal cord and brain stem to the cerebrum, where the stimuli are perceived as touch, pain, pressure, heat, or cold, or some combination, and their locations on the skin surface are registered.

MATERIALS PER STUDENT LAB GROUP: See tables in "Materials and Equipment" in ATE front matter. See "Advance Preparations" in ATE front matter.

ACTIVITY 3: SENSING STIMULI

Your nervous system is constantly being supplied with information both from your surroundings and from inside your body. Each bit of information is called a *stimulus* (plural, *stimuli*).



The parts of your sensory nerves that are sensitive to stimuli are called sensory nerve *endings*. They are the receivers of your body's communication network. Their job is to sense or receive stimuli and turn them into nerve messages. Your sensory nerves then carry the messages to your spinal cord and brain.

3-1. They are the parts of sensory nerves sensitive to stimuli. They receive stimuli and change them into nerve messages.

☆3-1. What are sensory nerve endings? What do they do?

Note that although five sense organs are described, only one, the skin, is used in the following investigation.

The sensory nerve endings that receive stimuli from your surroundings are found in your sense organs. Look at Figure 3-1 below and on page 11. Different kinds of sensory nerve endings can receive certain kinds of stimuli without being affected by other kinds. Thus, you receive light stimuli by means of the sensory nerve endings in your eyes, not the ones in your nose. And you receive taste stimuli through the sensory nerve endings in your tongue, not those in your kneecaps. You might say that each sense organ is tuned to its own channel.

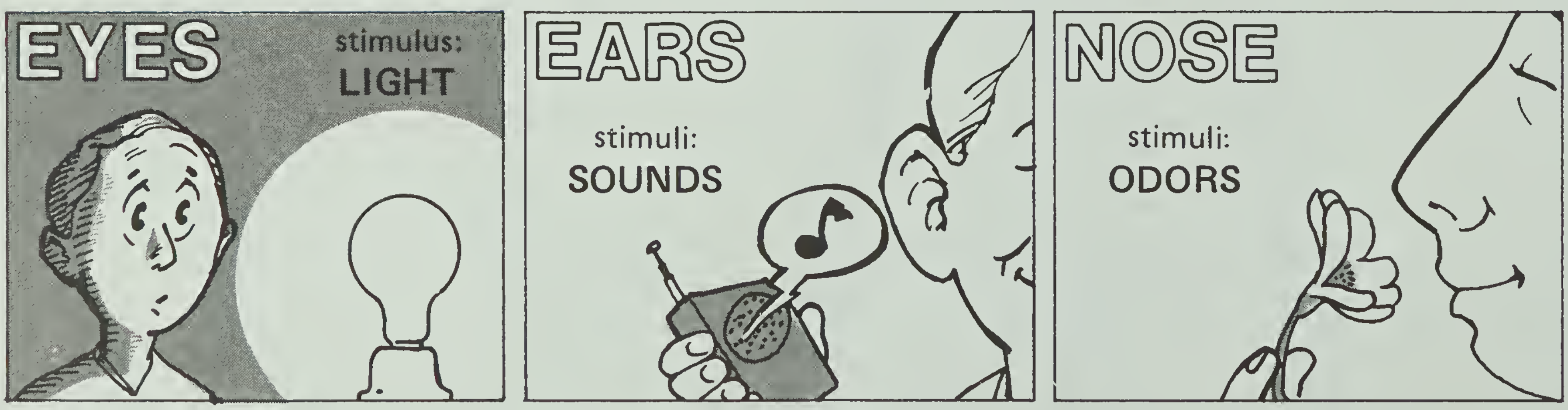


Figure 3-1 (continued on page 11)

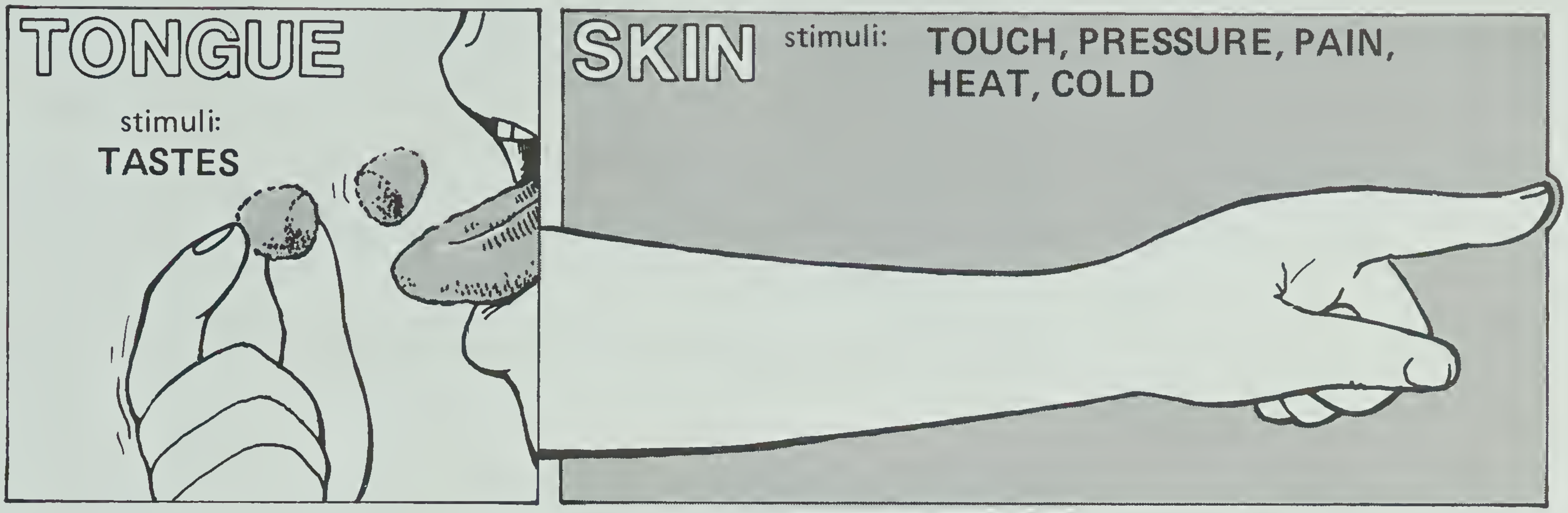


Figure 3-1 (continued from page 10)

☆**3-2. Name the sense organs where sensory nerve endings are located.**

3-2. Eyes, ears, nose, tongue, and skin

• 3-3. In what sense organs do you receive sound stimuli by means of sensory nerve endings?

3-3. Ears

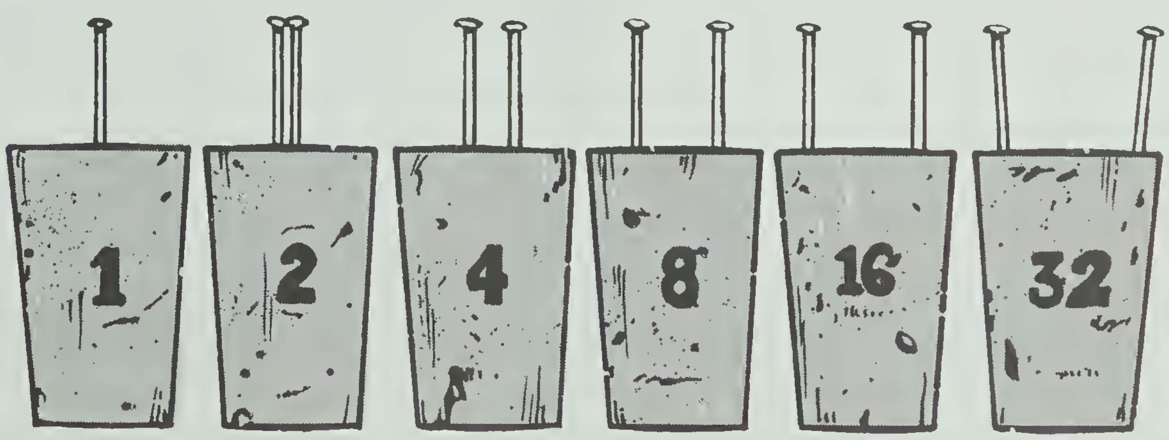
Now, investigate some sensory nerve endings of the skin. In this investigation, you'll be studying the sense of touch. You'll need a subject (a person not doing this minicourse) and the following materials.

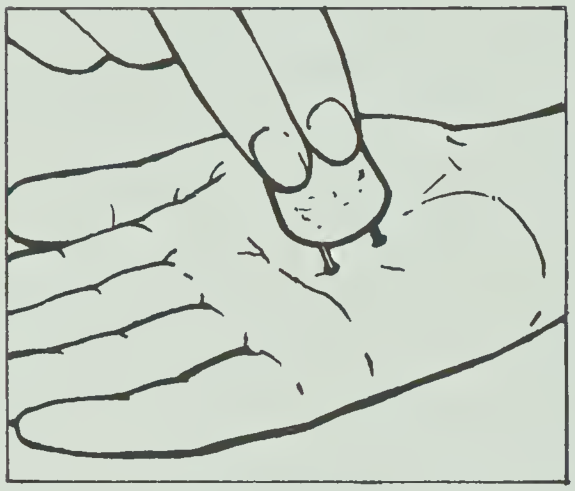
set of six Touch Testers
blindfold

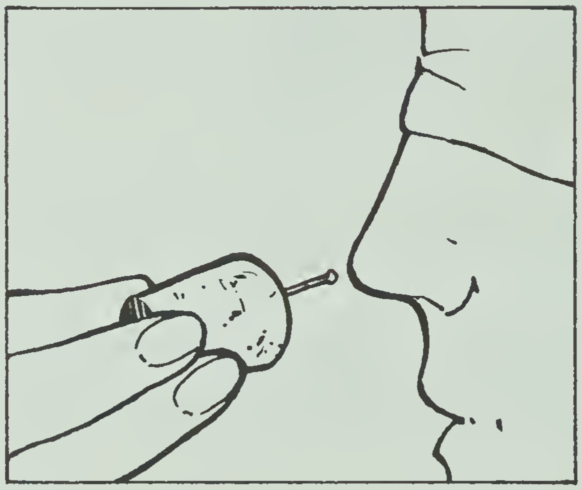
A. In your notebook, make a table similar to this one.

DISTRIBUTION OF NERVE ENDINGS OF TOUCH						
	Number of Contacts Felt with Tester					
Skin Area	Tester 1	Tester 2	Tester 4	Tester 8	Tester 16	Tester 32
Palm of hand						
Back of neck						
Back of hand						
Ball of thumb						
Tip of nose						

B. Show your subject the Touch Testers. Explain that you will be testing several skin areas with each tester to see whether the subject feels one point of contact or two.







C. Blindfold your subject. Start by touching the subject's palm very lightly with Tester 1.

D. Ask how many contacts the subject felt. Record the answer in your table under Tester 1. Try again if the subject doesn't say "One."

E. Touch the subject's palm with the other five testers in any order. Each time, ask how many contacts are felt and record the answer in your table. (Hint: Use Tester 1 from time to time to keep the subject "honest.")

F. Repeat the process, using each of the testers on the other skin areas listed in the table. Record the subject's answer after each test.

Your completed table gives you an idea of how the skin's sensory nerve endings are spread around. Whenever one contact was felt, only one sensory nerve ending was being affected by the tester (the stimulus).

3-4. Two [assuming they arise from different nerve fibers]

● 3-4. How many sensory nerve endings were being affected when two contacts were felt?

The number on each tester is the distance in millimetres between the two pinheads. For example, the pinheads on Tester 2 are 2 mm apart. Those on Tester 4 are 4 mm apart, and so on. The lower the number of the tester first felt as two contacts in each area, the closer together the sensory nerve endings are in that area.

3-5. [Answers may vary but will usually be the ball of thumb and back of neck.]

● 3-5. In which of the areas you tested are the sensory nerve endings closest together? Farthest apart?

3-6. The ball of the thumb is. The sensory nerve endings are closest together there.

● 3-6. Which of the areas you tested is most sensitive to touch? Why?

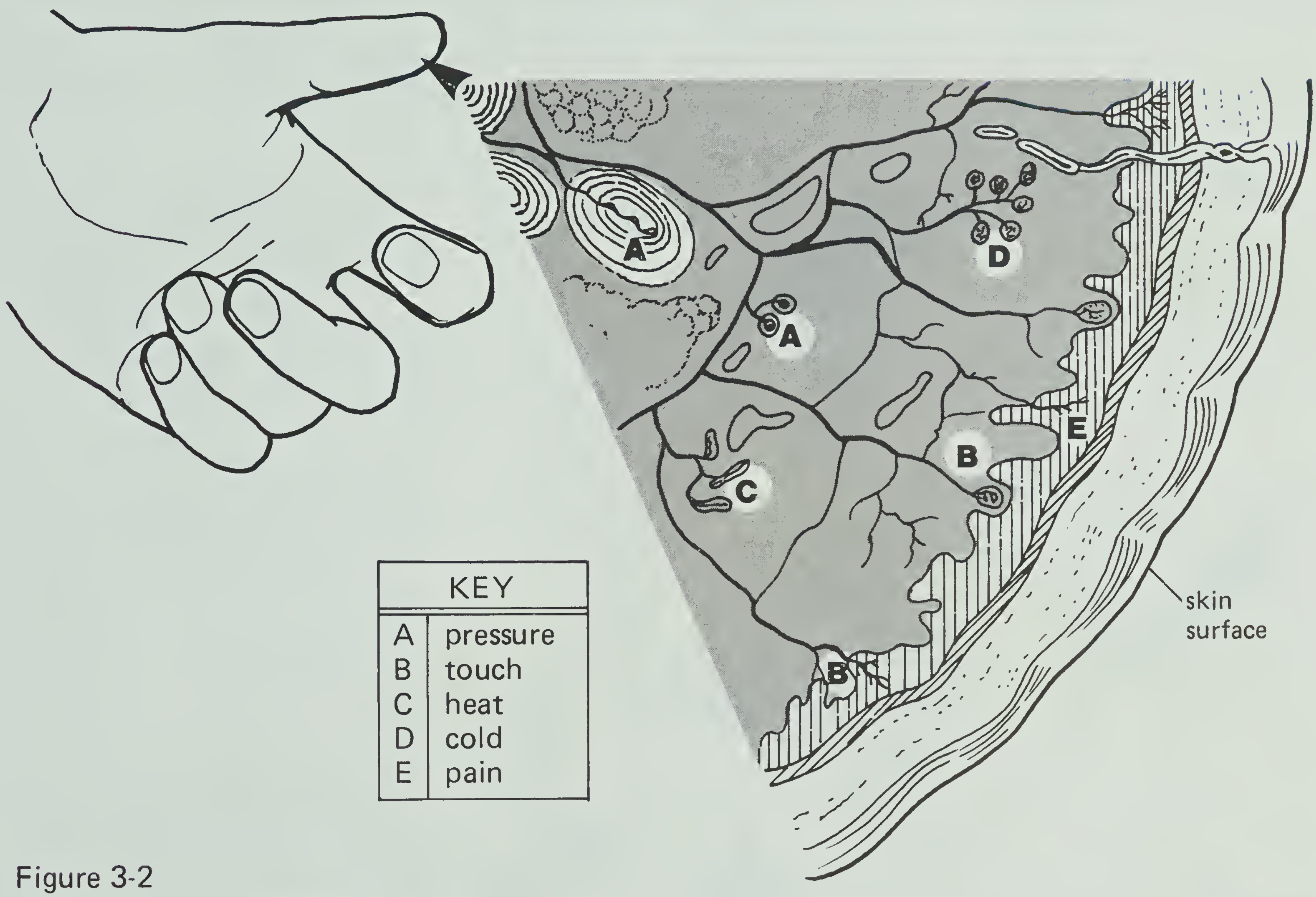
The closer together sensory nerve endings are, the more there are in an area. And the more nerve endings in an area, the more sensitive the area is to stimuli.

Your skin is a very complex sense organ. It has sensory nerve endings not only for touch stimuli but also for pressure, pain, heat, and cold stimuli. Itching, burning, tickling, and crawling sensations are probably combinations of these stimuli.

☆ **3-7. What are the stimuli that skin sensory nerve endings change into nerve messages?**

3-7. Cold, heat, pain, pressure, and touch

Each type of sensory nerve ending in your skin is different. Look at Figure 3-2 below.



KEY	
A	pressure
B	touch
C	heat
D	cold
E	pain

Figure 3-2

● 3-8. Which two kinds of sensory nerve endings are closest to the surface of the skin?

3-8. Touch and pain

Perhaps your most sensitive nerve endings for touch are the ones attached to the hairs in your skin. Look at Figure 3-3 (page 14).

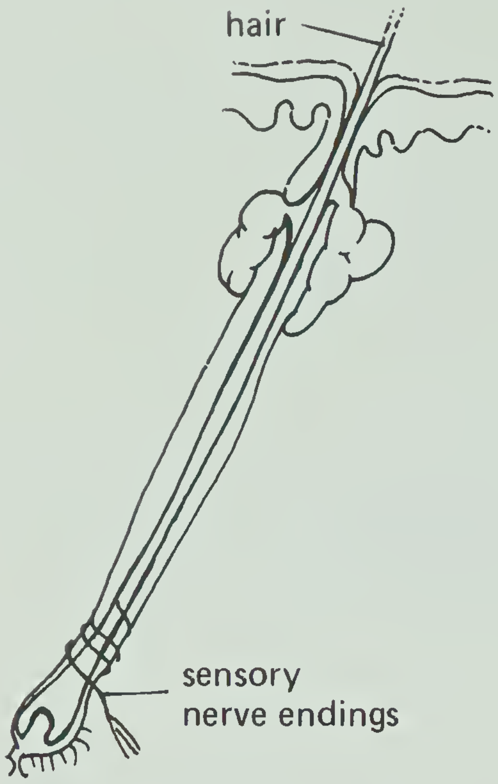


Figure 3-3

A bundle of sensory nerve endings surrounds the base of each hair. When just one hair is moved, these nerve endings receive the touch stimulus and turn it into a nerve message. A sensory nerve sends the nerve message to your spinal cord, up to your brain stem, and finally to the touch area of your cerebrum. When the message reaches your cerebrum, you can tell where you were touched.

You can get an idea of how well people can locate where they are touched. You'll need a subject and a blindfold.

A. In your notebook, make a table similar to this one.

AREA TESTED	STIMULUS FELT (Yes or No)	STIMULUS LOCATED (Closeness in cm)

B. Have your subject sit comfortably in a chair, with hands on the knees. Put the blindfold in place. Explain that you will be testing the subject's sense of touch.

C. Using a pencil, carefully move one hair on your subject's arm. Ask the subject to touch the place stimulated. Record whether or not the subject felt the stimulus and how close in centimetres he or she located it.

D. Repeat Step C with hairs on other areas, such as the back of the hand, the upper arms, the face, and the back of the neck.

E. Change roles so that you become the subject. Repeat Steps B through D, having your partner tell you how close you were each time.

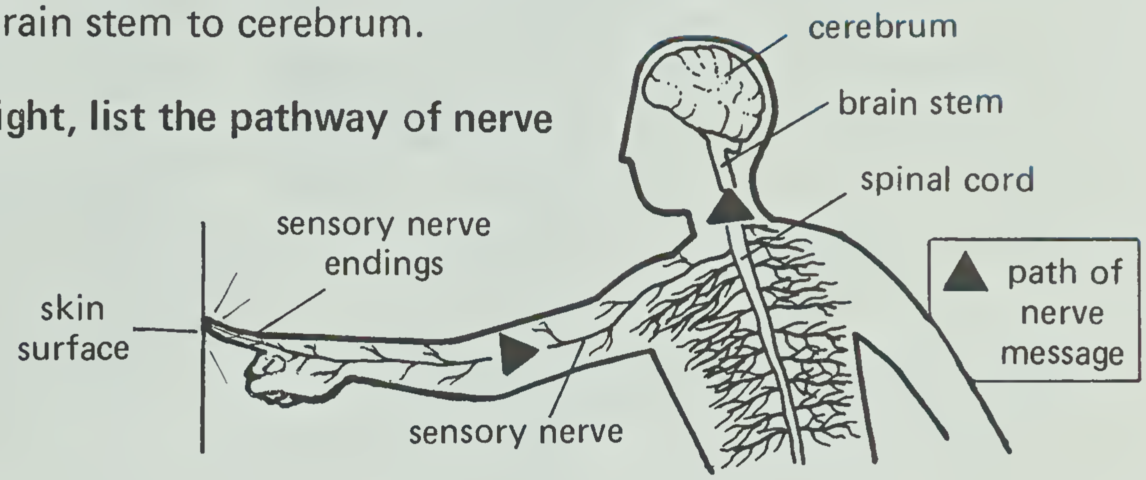
● 3-9. In which of the areas were you and your subject most accurate in locating the stimulus?

3-9. [Answers will vary, but possibly the face and the back of the hands.]

There are several other kinds of sensory nerve endings in the skin. All of them send messages to your brain in similar ways. The pathway is always from sensory nerve endings in the skin to sensory nerves to spinal cord to brain stem to cerebrum.

☆ **3-10. Using the drawing on the right, list the pathway of nerve messages from the skin to the brain.**

3-10. From sensory nerve endings to sensory nerves to spinal cord to brain stem to cerebrum



ACTIVITY 4: BRAIN AND BODY

ACTIVITY EMPHASIS: Conscious motor acts require sensing of stimuli by sensory nerve endings and transmission of sensory messages to the spinal cord and brain. Motor responses follow when motor messages from the cerebrum and cerebellum, carried through the spinal cord nerves and motor nerves, cause one of a paired set of voluntary muscles to contract while the other relaxes.

MATERIALS PER STUDENT LAB GROUP: See tables in "Materials and Equipment" in ATE front matter.

Perhaps the most amazing thing about human beings is their ability to control many of their own actions. You notice things around you, think about them, and decide what to do. Then you often can do whatever you have chosen to do. Sometimes the whole process happens very quickly.

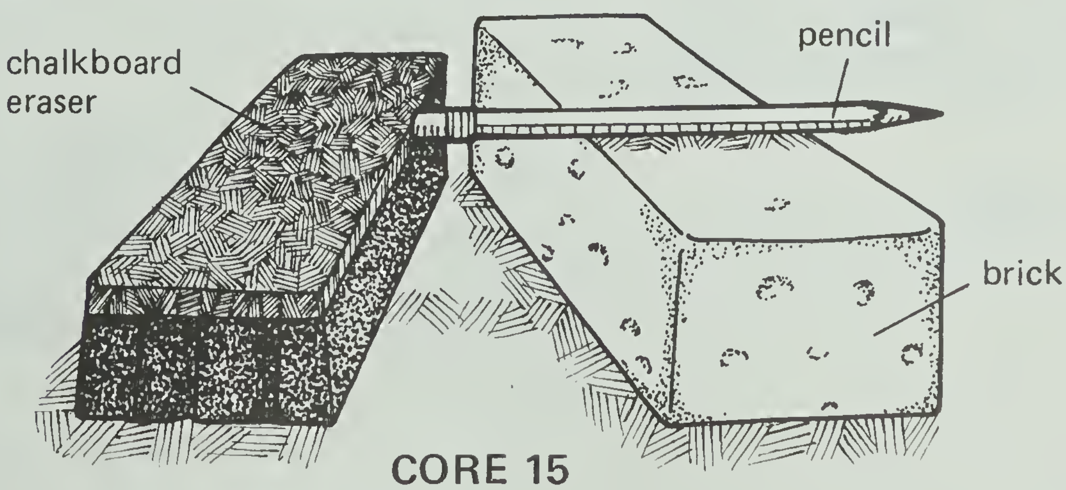
To understand what this involves, try this investigation. You'll need a subject (a person not working on this minicourse) and the following materials. You might want to do this investigation with a partner.

blindfold
chalkboard eraser
pencil
brick

A. Copy this table into your notebook.

STIMULUS	REACTION OF RIGHT HAND
Pencil	
Eraser	
Brick	

B. Show your subject the eraser, pencil, and brick. Explain that you will place them in the subject's hand, one at a time, to observe the subject's muscle reactions.



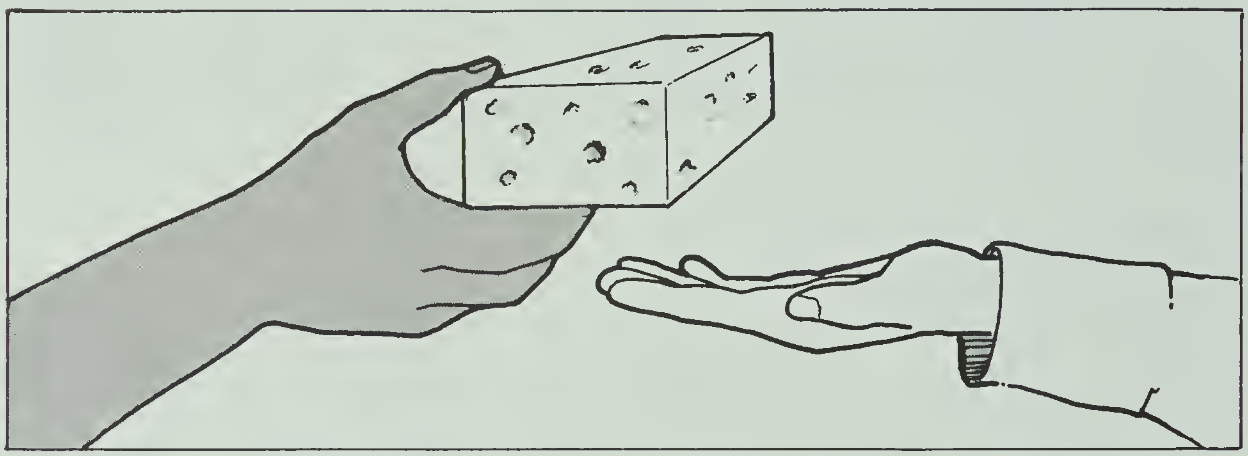
C. Blindfold your subject. Have the subject stand relaxed, with the left arm out and the palm up.

D. Place one of the objects slightly off center in the subject's left hand. The idea is to make the subject sense that the object might fall. As you do this, watch what the subject's right hand does.

E. Remove the object. Record your observation in your table.

F. Repeat Steps D and E with the other two objects.

G. Remove the blindfold. You are finished with the subject.



4-1. The pencil, the eraser, and the brick

4-2. [Answers will vary. With the brick, there was most likely a definite movement of the right hand toward the left and not so much with the other objects.]

4-3. The brain

● 4-1. What stimuli did you place in the subject's left hand?

● 4-2. How did the subject's right hand respond to the three stimuli?

● 4-3. What body part was responsible for moving the right hand?

The brain is responsible for most body actions, even those you aren't really aware of. Figure 4-1 (page 17) shows how a stimulus, such as the weight of a brick, can lead to the response you observed. Study the diagram and then answer the questions that follow it.

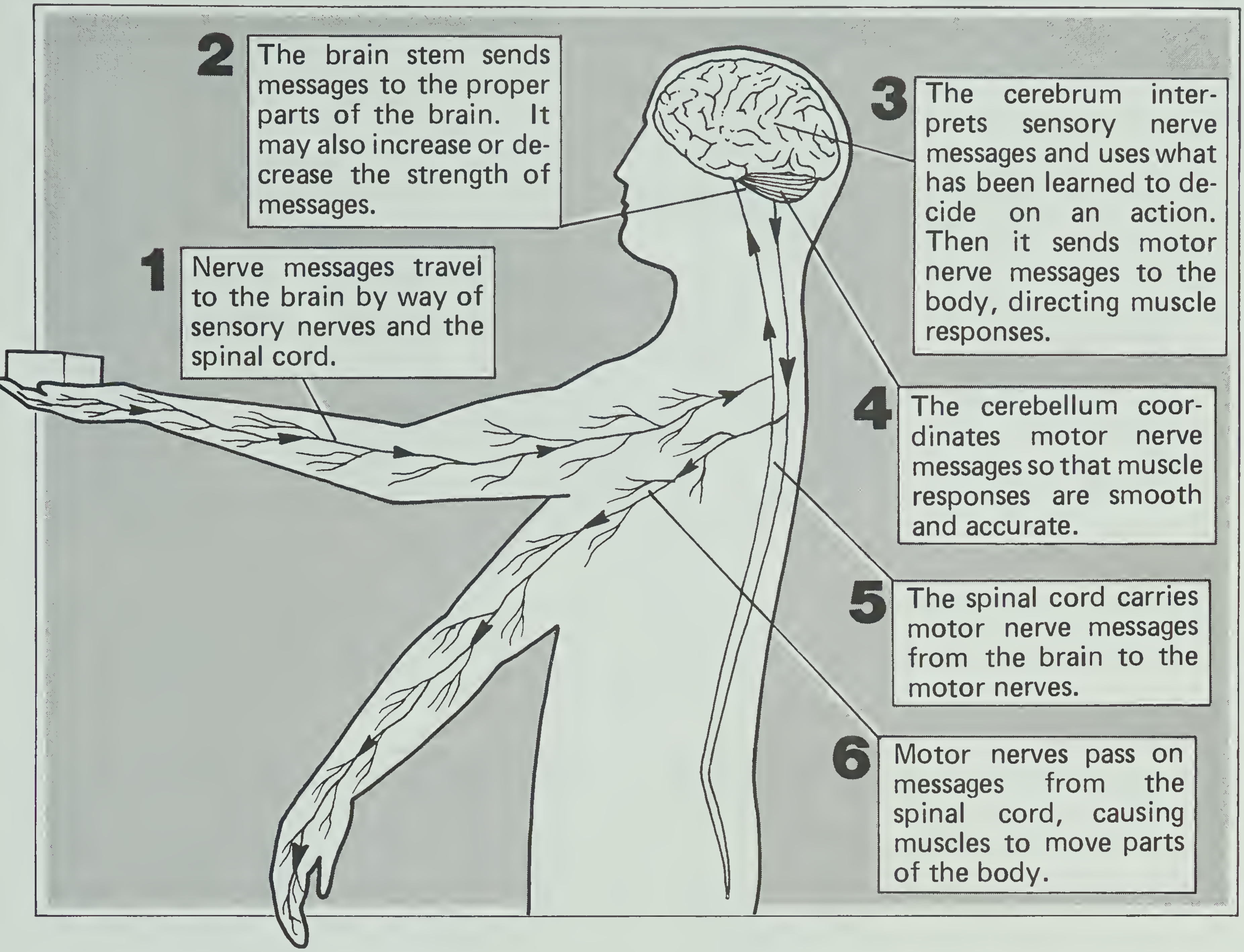


Figure 4-1

● 4-4. What parts of the brain are involved in controlling the movement of body parts?

4-4. The cerebrum and the cerebellum

☆ 4-5. What is the role of the cerebrum in sending motor nerve messages? The role of the cerebellum?

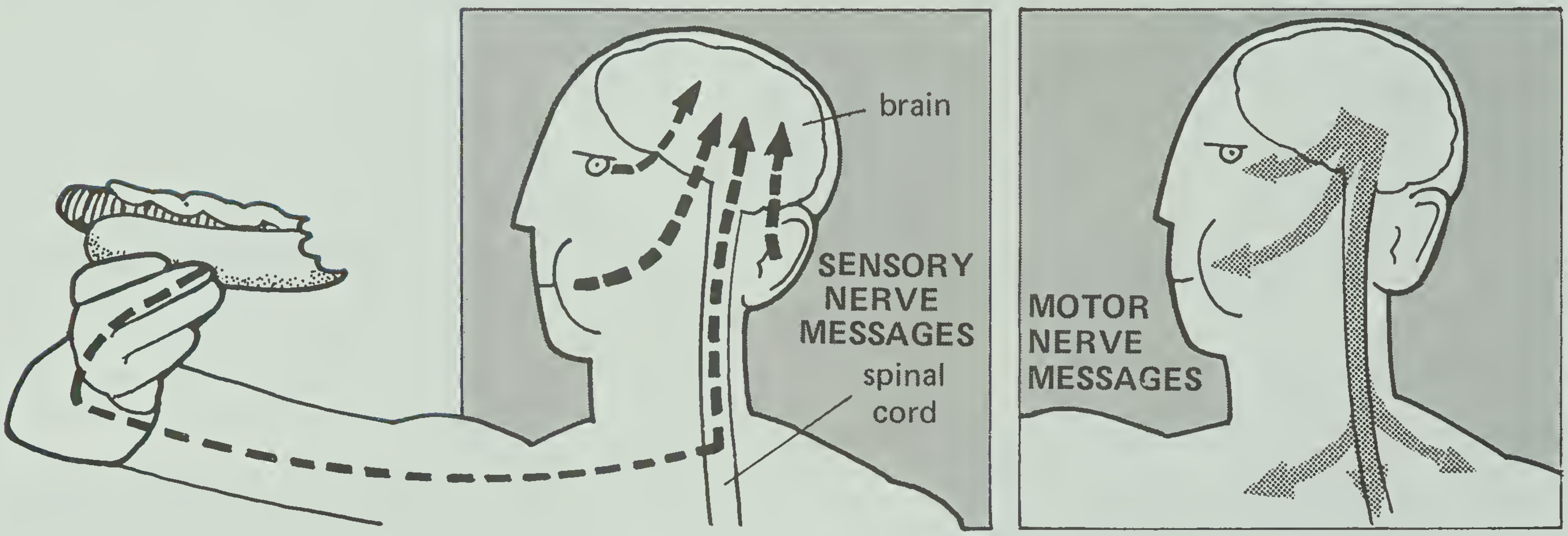
4-5. Decides on the action and sends motor messages; coordinates motor message so muscles respond smoothly and accurately

☆ 4-6. Suppose a would-be swimmer is testing the water in a lake by dipping in a toe. What part of the nervous system makes the decision whether or not to jump in? After the swimmer decides to jump in, motor nerve messages are sent to the leg muscles. Name, in order, the parts of the nervous system that these messages pass through.

4-6. The cerebrum; from the cerebrum to the cerebellum to the spinal cord to motor nerves

Cranial nerves may be sensory, motor, or mixed. Nine of the eleven cranial nerves that arise from the brain stem are mixed or motor; motor messages go via these nerves directly to voluntary muscles in the head and face.

Not all nerve messages reach the brain in the same way. The sensory nerve endings in your skin send sensory messages to your brain by way of the spinal cord. But those in your other sense organs -- eyes, ears, nose, and tongue – send messages directly to the brain. In response to these messages, the brain sends motor nerve messages to most muscles by way of the spinal cord and motor nerves. But a few muscles, mostly in the head, receive messages directly from the brain.



Any body action that depends on conscious choice is called a *voluntary* action. All voluntary actions are directed by the brain. (In Activities 7 and 8, you'll find out more about actions you don't consciously control.)

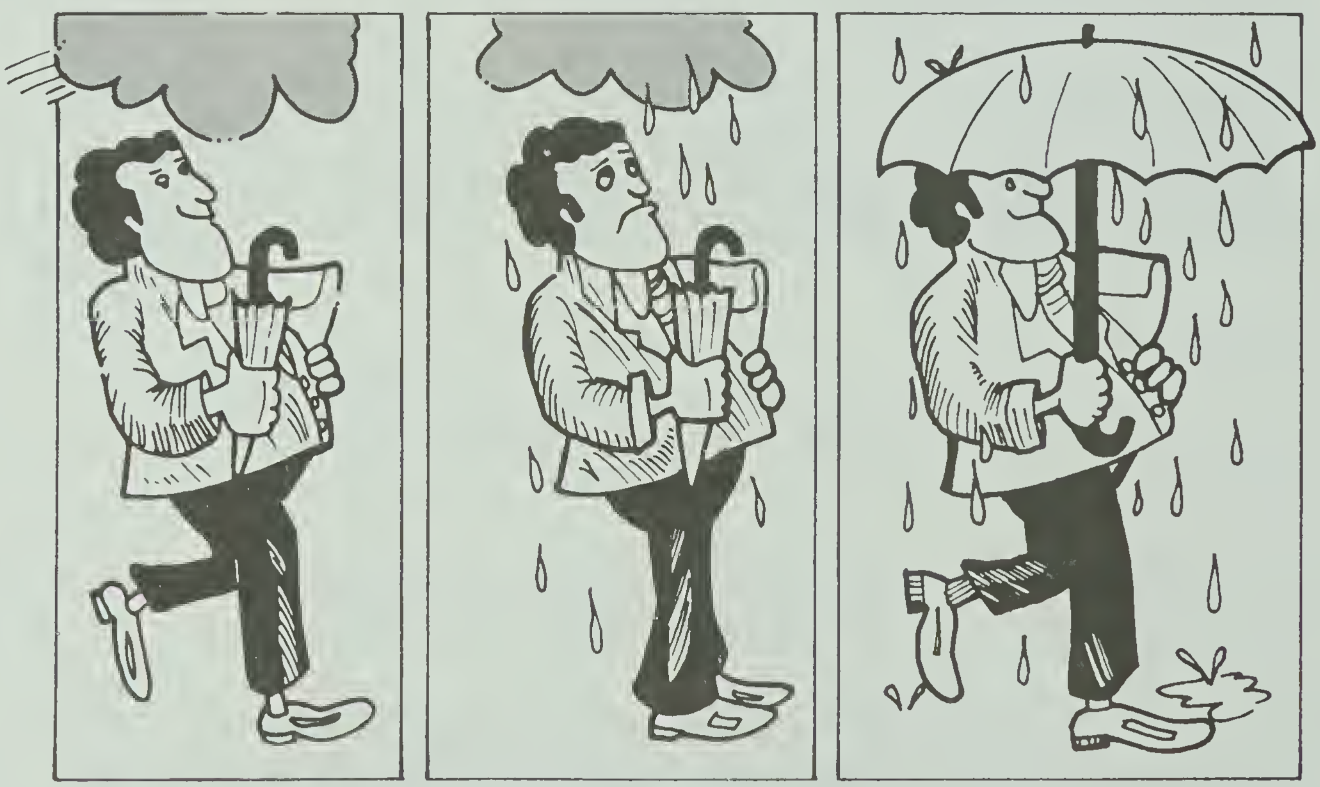


Figure 4-2

4-7. Yes; the person consciously chose to stop walking, look up, open the umbrella, and start walking again.

• 4-7. Notice the body actions shown in Figure 4-2 above. Are they voluntary? Explain your answer.

Voluntary actions always involve the contracting and relaxing of voluntary muscles. These are the muscles that you can use your brain and motor nerves to control. Figure 4-3 below shows the names and locations of a few of the many voluntary muscles in the human body.

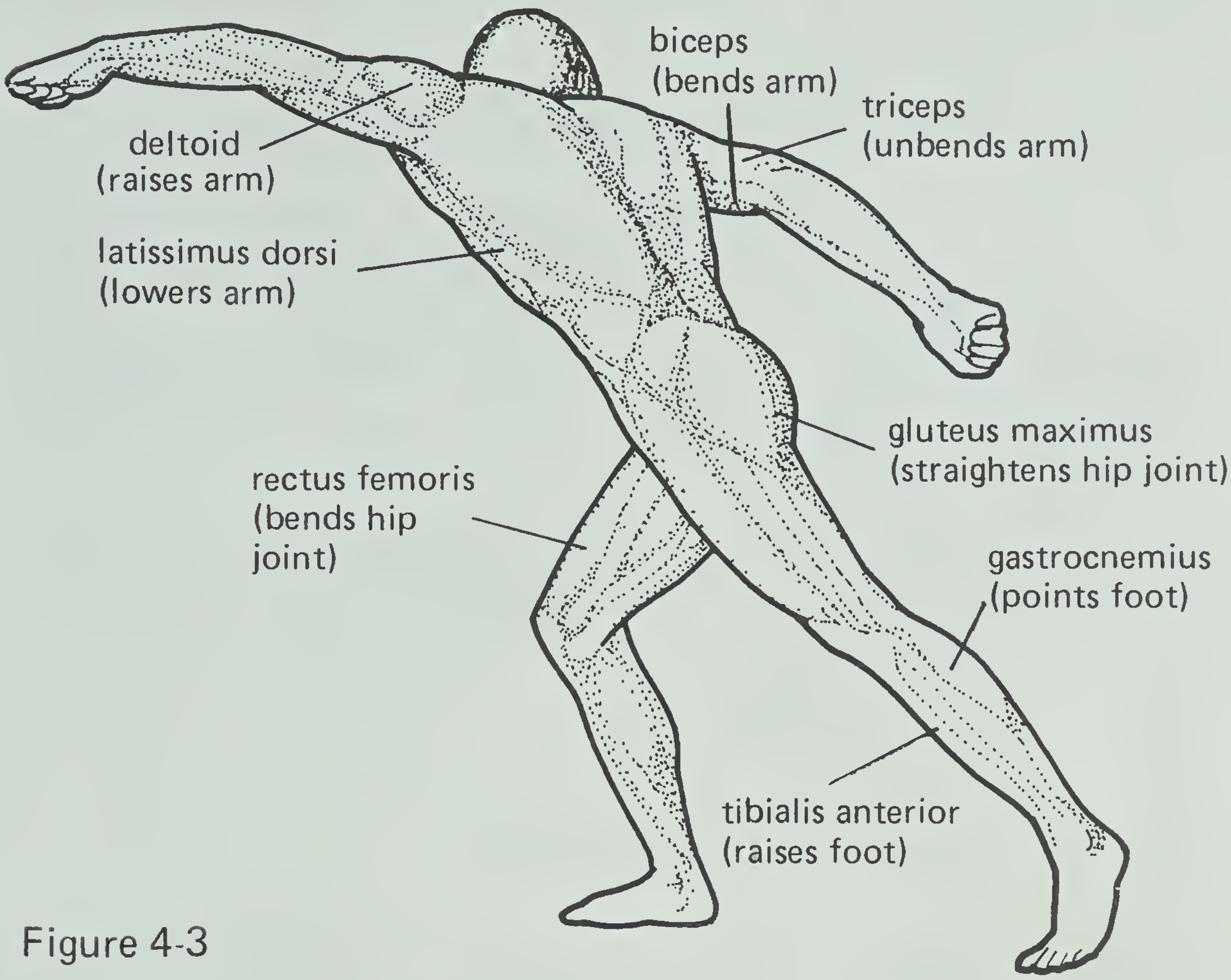


Figure 4-3

The muscle pairs shown here are just a few examples of the great number of voluntary muscles.

Now think about holding a brick in your left hand. You might choose to move your right arm so that it could help support the brick. Your arms bend only when certain muscles operate. Figure 4-4 below shows which voluntary muscles contract and relax to bend the arm.

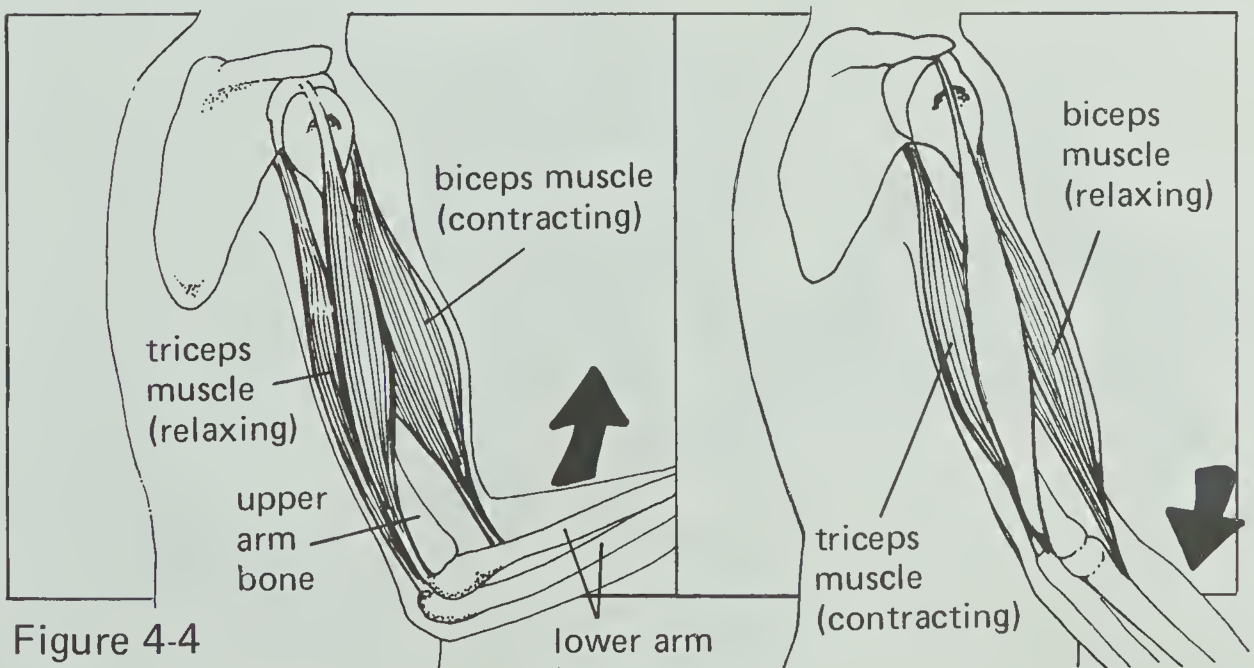


Figure 4-4

4-8. The biceps muscle; the triceps muscle

A steady stream of nerve messages to all muscles keeps them in a state of partial contraction called *tone*. A contract message sent to one muscle of a paired set increases the tone of that muscle and decreases the tone of the other muscle, which then relaxes.

4-9. One muscle of a paired set contracts; the other relaxes.

4-10. The triceps muscle

● 4-8. When you bend your arm, which voluntary muscle contracts? Which voluntary muscle relaxes?

Voluntary muscles must always work in paired sets to move body parts. When one muscle of a pair contracts, the other must relax. To bend the arm, the biceps muscle contracts and the triceps muscle relaxes.

☆ **4-9. How do voluntary muscle pairs move body parts?**

The brain sends motor nerve messages to voluntary muscles through the spinal cord and along the motor nerves. One muscle of each paired set is told to contract, which it does. At the same time, the other muscle of the pair doesn't get a message, so it relaxes. Most actions involve many voluntary muscle pairs operating at the same time.

● 4-10. Suppose you unbend your arm. Which muscle — biceps or triceps — is getting the contract message?

ACTIVITY EMPHASIS: The major parts of the eye involved in sight are the cornea and lens (focus light), the iris and pupil (control amount of light), the retina (senses light), and the optic nerve (carries messages to the brain). The iris reflex is under feedback control.

MATERIALS PER STUDENT LAB GROUP: See tables in "Materials and Equipment" in ATE front matter.

ACTIVITY 5: SIGHT AND FEEDBACK

Of all your sense organs, your eyes probably bring you the most information from your surroundings. They sense color, size, shape, position, movement, and distance.

The working of the eyes involves the nervous system in several ways. Before going into that, let's look at the structure of the human eye. Figure 5-1 below gives two views of the main parts of the eye.

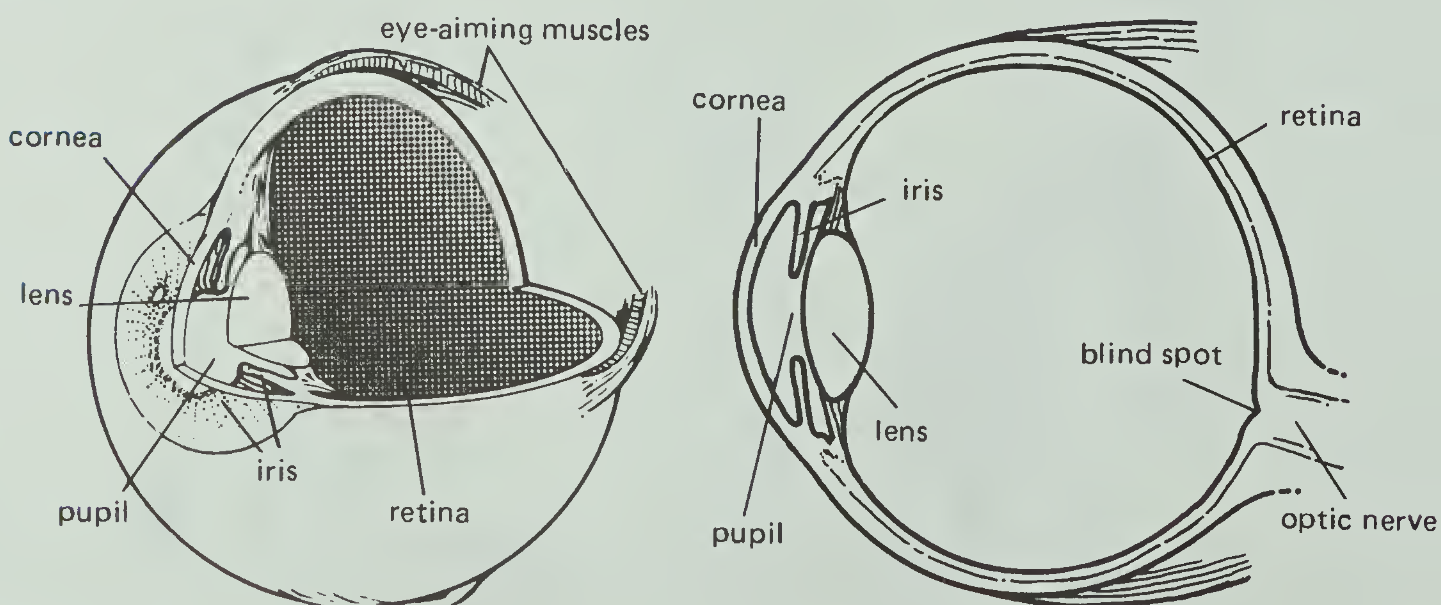


Figure 5-1

The pupil is the black opening in the center of the eye. Light enters the eye through it. Around the pupil is the iris, a colored circle of muscles. The iris changes the pupil's size to admit more or less light. The cornea is the transparent covering over the pupil and iris. Together with the lens, it focuses light to form images inside the eye. These images are focused on the retina, the inside back lining of the eyeball. Sensory nerve cells in the retina change light stimuli into nerve messages. The optic nerve then carries these messages to the sight center of the brain.

To learn a little more about your eyes, you'll need a partner and the following materials. Refer to Figure 5-1 on page 20 or a human eye model as you do this investigation.

You may want to have a model of the human eye available for students to use.

hand lens
penlight

A. Use the hand lens to look closely at one of your partner's eyes. Find the pupil and the iris of the eye.

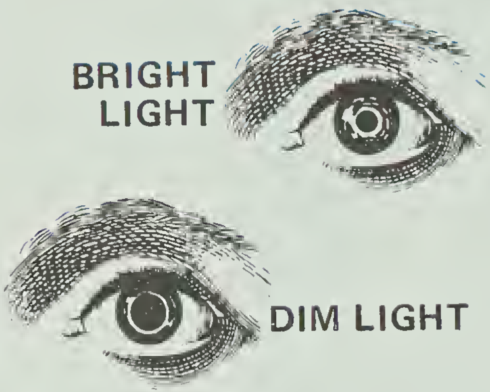
B. From the side, look at the bulge of your partner's eye — the cornea.

● 5-1. Describe the pupil, the iris, and the cornea.

5-1. [Answers will vary but should mention dark or black pupil, the color of the iris, and the clear cornea.]

C. Using the penlight, try to look through the pupil at the retina.

5-2. [Answers will vary but probably nothing, since the iris muscles will close the pupil somewhat.]



The iris also closes the pupil to increase depth of field for near objects (near vision).

Dark and light adaptation occurs in the rods in the retina under different lighting conditions also.

5-3. Opened

A red reflection when light is shone at the pupil is due to reflection from the retina.

5-4. It changes the size of the pupil.

5-5. A3e; B2d; C4b; D1a; E1c

● 5-2. What did you see when trying to look through the pupil?

You probably noticed that your partner's pupil got smaller when you shone the light at it. If not, try Step C again. Observe the pupil carefully as you shine the light and as you remove it.

As light conditions change, your iris opens the pupil or closes it. Your iris closes the pupil to keep too much light from entering. And it opens the pupil to allow extra light to enter. These adjustments help you see better in different lighting conditions.

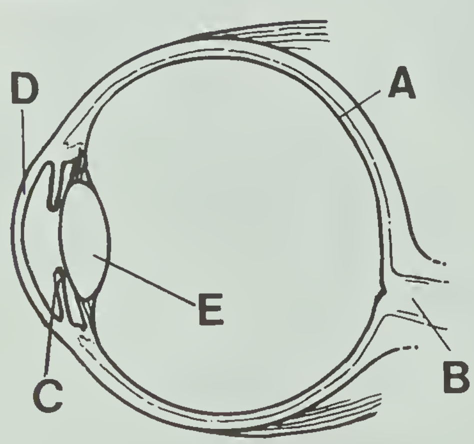
● 5-3. In dim light, is your pupil opened or closed?

With no conscious effort on your part, your brain controls how much light enters your eyes. This kind of involuntary (usually unconscious) response to a stimulus is called a *reflex*. The stimulus that brings about the iris reflex is the amount of light falling on the retina.

● 5-4. How does the iris respond to changing amounts of light?

☆ **5-5. Now check yourself on the eye. Match each lettered part of the eye with its function and its name.**

Eye Part



Function

1. helps focus light
2. carries nerve messages
3. changes light stimuli into nerve messages
4. controls amount of light entering eye

Name

a. cornea
b. iris
c. lens
d. optic nerve
e. retina

Your brain controls the iris reflex, and your body's other involuntary actions, by means of sensory messages called *feedback*. Using feedback, the brain adjusts the iris to let just the right amount of light into the eye. Figure 5-2 below shows how this feedback control works.

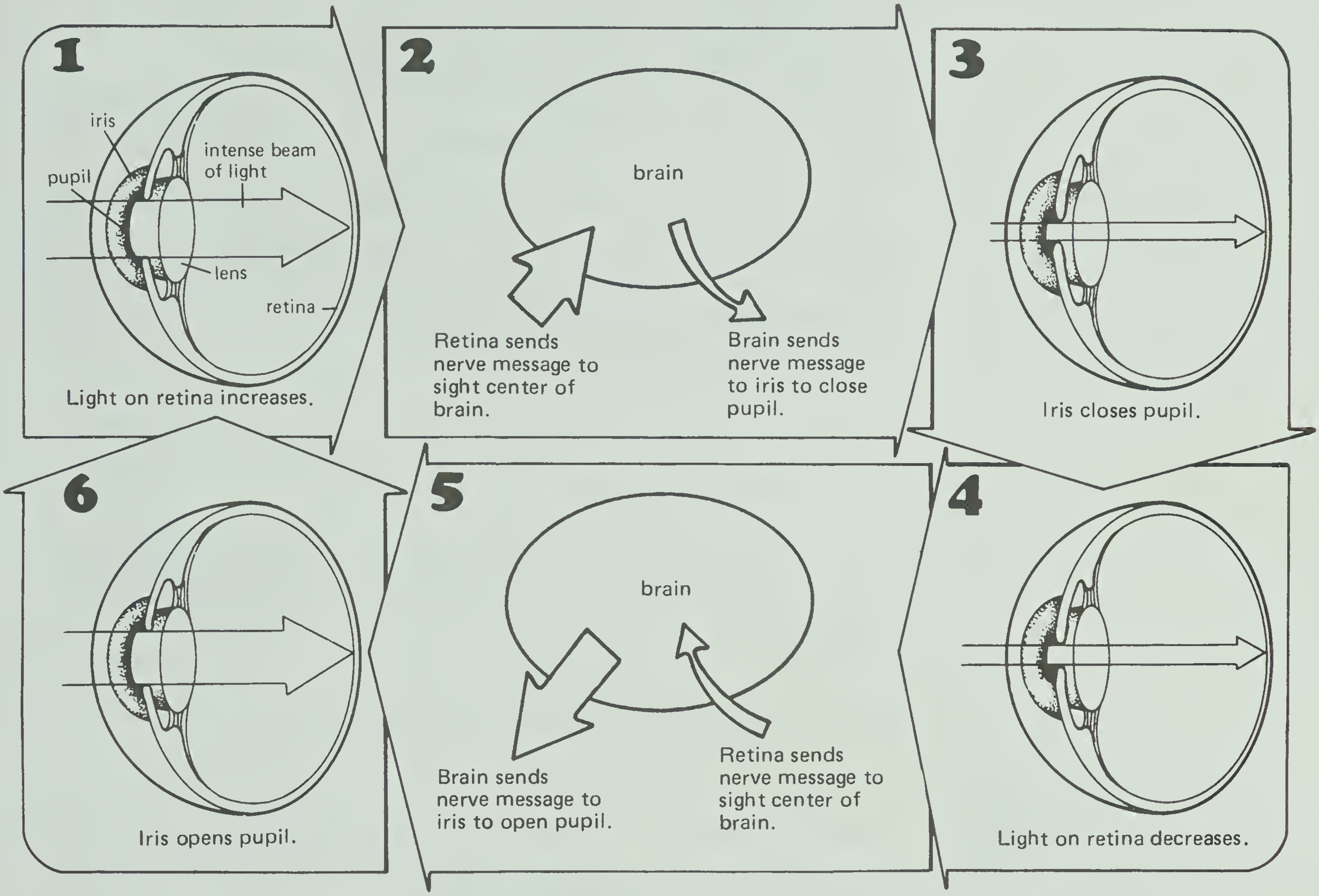


Figure 5-2

☆ **5-6. What part of the nervous system is responsible for receiving feedback and sending nerve messages to control the iris reflex?**

5-6. The brain

☆ **5-7. What stimulus provides feedback that controls the iris reflex?**

5-7. The stimulus is the amount of light. [Distance of object also provides feedback — near vision.]

If this is the first time you've met the idea of feedback control, don't worry if you feel you don't completely understand it. You'll see the idea in other minicourses. If you've studied feedback before and still aren't sure about it, you might want to read through "Resource Unit 13: Systems and Feedback."

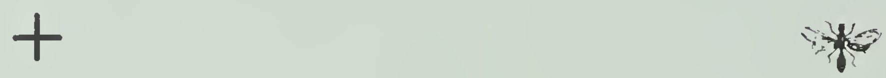
5-8. 3, 6, 5, 2; then 4, 6, 5, 1

• 5-8. Suppose someone shines a bright flashlight beam into your eyes and then turns it off again. Some of the following feedback control steps will be involved.

1. The iris opens.
2. The iris closes.
3. Light on the retina increases.
4. Light on the retina decreases.
5. The brain sends a message to the iris.
6. The retina sends a message to the brain.

What four steps will occur in order when the light is turned on? What four steps will occur in order when the light is turned off?

Look back again at Figure 5-1 (page 20). Notice the label *blind spot* at the place in the retina where the optic nerve attaches. There are no sensory nerve endings at this point, so light that falls there isn't sensed. To find your blind spot, try the disappearing-ant demonstration in Figure 5-3 below.



Close your left eye and focus your right eye on the cross. Move your head slowly toward and away from the drawing. At a distance of 15 cm to 20 cm, the ant will seem to disappear.

Figure 5-3

• 5-9. Why does the ant seem to disappear?

5-9. Light from the ant is falling on the blind spot in the retina, where there are no sensory nerve endings to receive the stimuli and change them into nerve messages.

ACTIVITY EMPHASIS: The causes, effects, symptoms, and treatments of the following ten nervous system conditions are described by means of the game Diagnosis: brain injury, brain tumor, cerebral palsy, encephalitis, epilepsy, meningitis (bacterial), multiple sclerosis, Parkinson's disease, spinal-cord injury, and stroke.

MATERIALS PER STUDENT LAB GROUP: See tables in "Materials and Equipment" in ATE front matter. See "Advance Preparations" in ATE front matter.

ACTIVITY 6: DIAGNOSIS

Perhaps the most frightening diseases and accidents are those involving the central nervous system – the brain and spinal cord. They seem to threaten the victim's control over his or her own actions. But many problems of the nervous system can be cured or at least controlled. With proper treatment, the victims may continue to lead full lives.

In this activity, you will play the Diagnosis Game. The game may take two or three class periods, so plan your time. It will help you learn about the causes, effects, symptoms, and treatments of nervous system conditions. Begin by reading the rules on the back of the "Doctor's Memory Card." When you finish Round 3, answer the questions on pages 25 and 26.

To play, you'll need a partner, paper for keeping score, and the game (1 "Doctor's Memory Card" and 10 "Patient Cards").

CAUTION	The conditions described in the Diagnosis Game are serious. Self-diagnosis and self-treatment can be dangerous. Seek medical aid when you feel ill. The Diagnosis Game is for information only.

● 6-1. During an examination, how can a doctor tell what part of the brain is affected by a stroke, head injury, or tumor?

6-1. By checking for sensations and muscle movement in parts of the body (including eyes)

☆ 6-2. Match each condition with its possible symptoms and signs. (Answers may be used more than once.)

Condition	Possible Symptoms and Signs
A. Brain injury	1. headache
B. Brain tumor	2. abnormal EEG pattern
C. Cerebral palsy	3. vomiting
D. Encephalitis	4. paralysis
E. Epilepsy	5. small red spots on trunk
F. Meningitis	6. abnormal spinal fluid
G. Multiple sclerosis	7. convulsions
H. Parkinson's disease	8. swollen optic-nerve disk
I. Spinal-cord injury	9. muscle spasms, jerking, tremor
J. Stroke	10. abnormal X ray
	11. unconsciousness
	12. unequal pupil size
	13. impaired speech

6-2. A3, 4, 10, 11, 12, 13, (possibly 1 and 9); B1, 2, 3, 4, 6, 7, 8, 10; C4, 9, 13; D1, 3, 11, (possibly 7); E2, 7, 9, 11, (possibly 6); F1, 3, 5, 6, 11; G4, 6, 13, (possibly 9); H9, 13; I4, 9; J4, 11, 12, 13

☆ 6-3. Match each condition with its causes and effects. (Answers may be used more than once.)

Condition	Causes and Effects
A. Brain injury	1. infection
B. Brain tumor	2. poisonous chemicals
C. Cerebral palsy	3. accident or injury
D. Encephalitis	4. pressure in skull
E. Epilepsy	5. damaged brain cells
F. Meningitis	6. damaged nerves
G. Multiple sclerosis	7. overactivity of brain cells
H. Parkinson's disease	
I. Spinal-cord injury	
J. Stroke	

6-3. A3, 4, (possibly 5); B4, C3, (possibly 1, 2, and 5); D1, 4; E1, 2, 3, 7; F1, 4, (possibly 6); G5, 6; H2, 5, 6; I3, 6; J5, (possibly 4)

☆ 6-4. For which of the conditions listed in Question 6-3 above is surgery a possible treatment?

6-4. Brain injury, brain tumor, epilepsy, Parkinson's disease, spinal-cord injury, stroke

6-5. Brain tumor, encephalitis, epilepsy, meningitis, Parkinson's disease, stroke

6-6. Cerebral palsy, multiple sclerosis, Parkinson's disease, spinal-cord injury, stroke

Bracketed sample answers shown in the table below appear in ATE only.

☆ 6-5. For which of the conditions listed in Question 6-3 (page 25) are medications used to relieve symptoms?

☆ 6-6. For which of the conditions listed in Question 6-3 (page 25) is physical therapy used?

There's a lot of information in the Diagnosis Game. Making a summary is one way to help remember the important ideas. You'll need the game, a sheet of paper, and a ruler or straight-edge.

SUMMARY OF NERVOUS CONDITIONS

Condition	Symptoms	Causes and Effects	Treatments
Brain injury	[unconsciousness; strong, slow heartbeat; bleeding]	[brain swells; maybe bleeding in brain]	[get medical aid; patient lying down; compress on wound]
Spinal-cord injury	[pain in neck; can't move head; muscle spasms]	[maybe broken spine; pressure on spinal cord]	[get medical aid; don't move patient; patient lying down]
Encephalitis	[headache; fever; nausea; blurred vision]	[infection of the brain, causing brain to swell]	[hospitalization; medications; aid life systems]
Meningitis	[headache; high fever; vomiting; stiff neck; reflexes lost]	[infection of membranes covering brain; pressure]	[hospitalization; antibiotics]
Cerebral palsy	[fingers, toes, face twitching; jerky motion; paralysis]	[injury or infection to brain motor-control centers]	[physical therapy; speech therapy; braces, supports]
Epilepsy	[unconsciousness; convulsions; lips bluish]	[abnormal activity of brain parts; loss of control]	[medications; possible surgery]
Multiple sclerosis	[sudden paralysis; loss of vision; deafness]	[hardening of nerve fibers, thus no messages carried]	[none; physical therapy as needed]
Parkinson's disease	[shaking of arms; slow movement; back hunched]	[causes unknown; maybe chemical damage to brain]	[medications; physical therapy; exercise]
Brain tumor	[headache; vomiting; vision problems; convulsions; paralysis]	[uncontrolled growing of brain cells, causing pressure]	[surgery; X-ray treatment; medications]
Stroke	[unconsciousness; partial paralysis; speech slurred]	[blood flow to brain interrupted, causing brain cells to die]	[hospitalization; medications; physical therapy]

A. On the sheet of paper, make a table similar to the one shown here. Notice that the conditions are grouped differently here from the way they are on the "Doctor's Memory Card."

B. Work through the three categories for each condition. Check the "Patient Cards" against the "Doctor's Memory Card." Try to list three or four short statements for each heading for each condition.

C. Compare your summary table with a classmate's.

D. Use your table to help you study for your minicourse test.

ACTIVITY 7: HOW ARE YOUR REFLEXES?

Fortunately for you, many of your muscle actions don't require conscious thought. These unconscious responses are called *reflex acts*. Experiments with animals have shown that these reflexes can occur even when the brain and spinal cord are no longer connected.

Reflex acts are natural and predictable in healthy people. Look at Figure 7-1 below.

ACTIVITY EMPHASIS: Reflexes involve the sensing of stimuli by sensory nerve endings and the transmittal of sensory messages to the spinal cord. Motor messages are then sent through motor nerves to motor nerve endings, causing muscles or glands to react. Reflex acts may result from either internal or external stimuli.

MATERIALS PER STUDENT LAB GROUP: See tables in "Materials and Equipment" in ATE front matter. See "Advance Preparations" in ATE front matter.

Figure 7-1

- 7-1. What is the usual reflex when an elbow touches a hot iron?

7-1. Withdrawal — jerking the elbow away

Withdrawal reflexes are one way the body protects itself. The withdrawal can take place even before the pain is sensed by the brain.

☆ **7-2. Tell what a reflex act is. Give an example.**

7-2. It's the body's unconscious and predictable response to a stimulus, for example, pulling the hand back from a hot object.

Reflexes are either external or internal, depending on the location of the sensory nerve endings that are stimulated. Many such endings are in the skin or other sense organs (eyes, ears, nose, and tongue). When those nerve endings are stimulated, an external reflex can occur. When sensory nerve endings inside the body — in muscles or organs — are stimulated, an internal reflex can occur. Figure 7-2 below illustrates both kinds of reflexes.

The accepted classification of receptors is *exteroceptors* (for external stimuli), *proprioceptors* (for muscle stimuli), and *interoceptors* (for visceral stimuli).

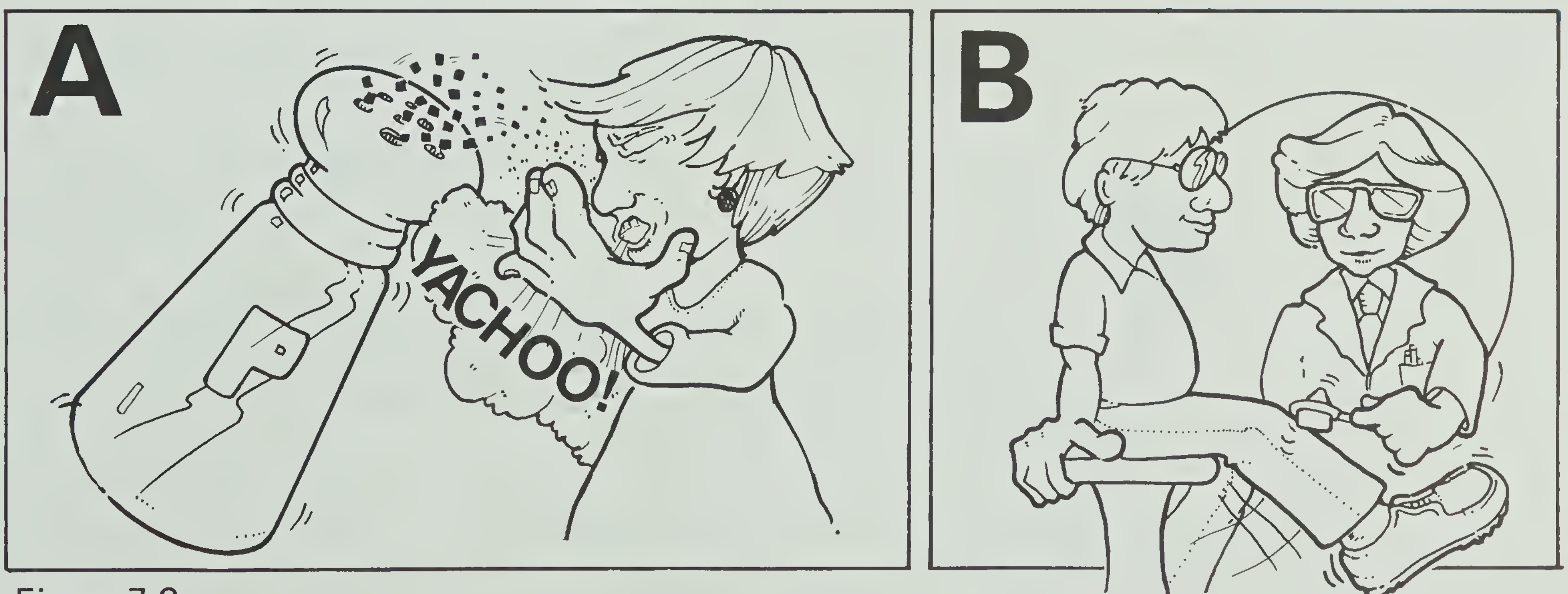
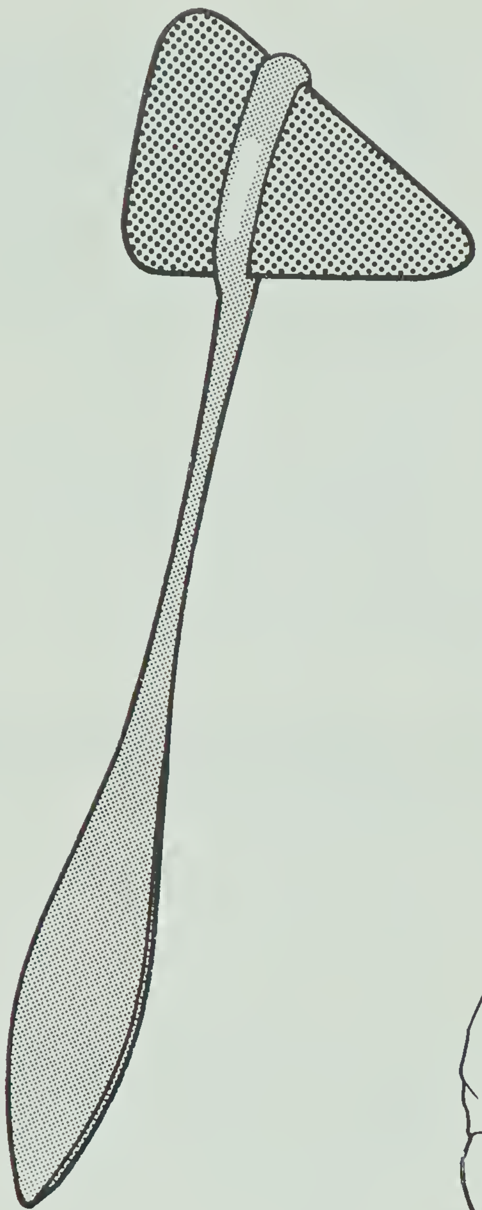


Figure 7-2

- 7-3. Which frame above — A or B — shows an external reflex?

7-3. Frame A



If you said Frame A shows an external reflex, you're right. Sensory nerve endings in the nose were stimulated by the pepper. In Frame B, sensory nerve endings in a muscle rather than in a sense organ were stimulated. The knee-jerk reflex is an example of an internal reflex known as a *muscle-stretch reflex*. This reflex involves a muscle's reaction to being stretched.

Look closer at the muscle-stretch reflex by trying an investigation. You'll need a partner and the following materials.

table
rubber mallet
straight chair

See ATE page 5 for additional cautions.

CAUTION	Tests on tendons should be done very carefully.

A. Have your partner sit on the table with legs hanging freely and not touching the floor. With the rubber mallet, tap firmly just below the kneecap.

7-4. The lower leg jerked upward.

- 7-4. What happened when you tapped just below the kneecap?

B. Now have your partner kneel on the chair, as shown, with feet hanging freely. Tap firmly with the mallet at a point just above the heel. Watch your partner's foot to observe the reflex.

● 7-5. What happened when you tapped just above the heel?

7-5. The foot jerked in a tiptoe direction.

In both parts of your investigation, you tapped a tendon, a band of fibers attached to a muscle. Tapping the tendon caused the muscle attached to it to stretch a little.

Tucked in among the muscle fibers are groups of muscle cells called *spindles.* Sensory nerve endings are wrapped around the spindles. When the muscle was stretched, the spindles were stretched too. This stimulated the nerve endings. It caused sensory nerve messages to start moving toward the spinal cord through sensory nerves.

Immediately, the spinal cord sent out motor nerve messages to contract. They traveled to the muscle through motor nerves. The muscle contracted, and the leg or foot jerked. Figure 7-3 below shows the pathway for the ankle-jerk reflex. Notice that these messages do not travel through the brain.

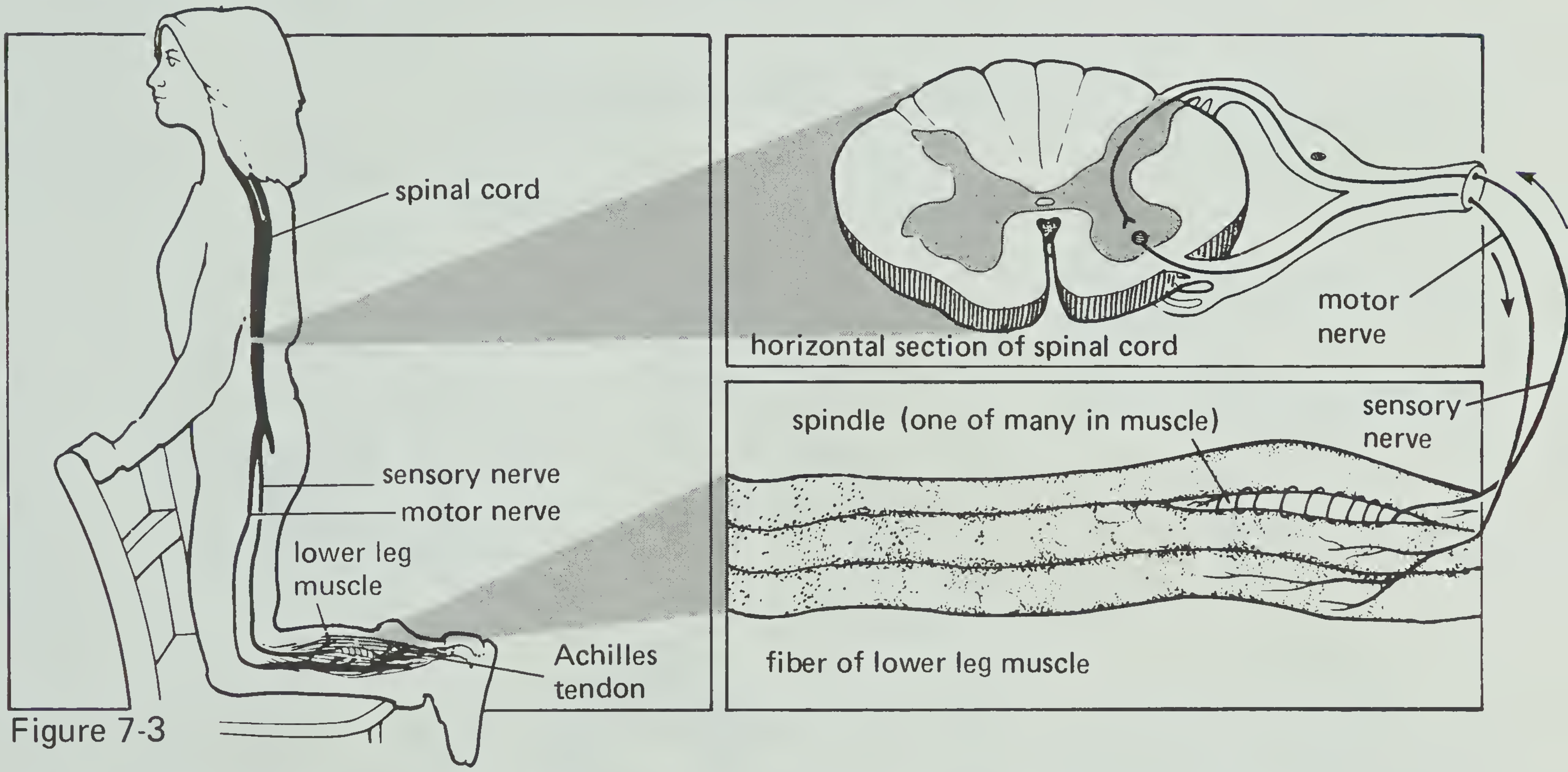


Figure 7-3

☆ **7-6. When the Achilles tendon is tapped, the ankle-jerk reflex occurs. List the steps below in the order in which they occur.**

A. Sensory nerve messages go from muscle to spinal cord by way of sensory nerves.

B. Muscle contracts and foot jerks.

C. Spindles in muscle are stretched and sensory nerve endings are stimulated.

D. Motor nerve messages come to muscle from spinal cord by way of motor nerves.

E. Motor nerve messages stimulate muscle.

7-6. C, A, D, E, B

Muscle tone is a small, steady contraction at rest and is maintained by muscle-stretch reflexes.

Another kind of muscle-stretch reflex is the one involved in posture. For example, when a person standing at attention begins to sway, some muscles are stretched. This brings about the muscle-stretch reflex. The stretched muscles contract a little, pulling the body back to the upright position.

7-7. A. External; B. muscle stretch; C. external; D. muscle stretch; E. external

☆ **7-7. Tell whether each of the following events is an external reflex act or a muscle-stretch reflex act.**

A. You duck when you see an object thrown at you.

B. Your lower arm moves when a tendon just above the elbow is tapped.

C. You blink when the surface of your eye is touched.

D. Your foot jerks when the tendon just above your heel is tapped.

E. Your hand pulls away when you touch a hot object.

ACTIVITY EMPHASIS: The brain controls internal organ processes through the autonomic part of the nervous system. Examples of autonomically controlled processes are given. The autonomic nerve pathway is from brain through spinal cord or directly to ganglia, then to effector organs.

MATERIALS PER STUDENT LAB GROUP: None

ACTIVITY 8: ON AUTONOMIC

Think about the last time you went outside on a cold morning without your coat to get something.

8-1. [Answers will vary, but they may include shivering, goose bumps, perhaps exposed skin turned red.]

● 8-1. What changes do you remember occurring in your body?

Your body responds to many kinds of stimuli, or bits of information, without conscious effort on your part. When you're cold, you begin to shiver, you get goose bumps, and your skin may turn red. You don't need to think about these responses for them to happen. And you have little or no control over them. Such responses are called *reflexes.*

Autonomic comes from *autonomous.* However, some people have learned through biofeedback to control some functions, such as heart rate.

The goose-bump reflex is an example of an autonomic [awt-ah-NOM-ik] reflex. The autonomic part of your nervous system regulates many internal body processes. It usually works by either speeding up a body process or slowing it down.

☆ 8-2. What is an autonomic reflex?

Figure 8-1 below illustrates some of the important internal body processes that the autonomic system regulates.

8-2. An unconscious response to a stimulus by which a body process controlled by the autonomic nervous system is usually either speeded up or slowed down

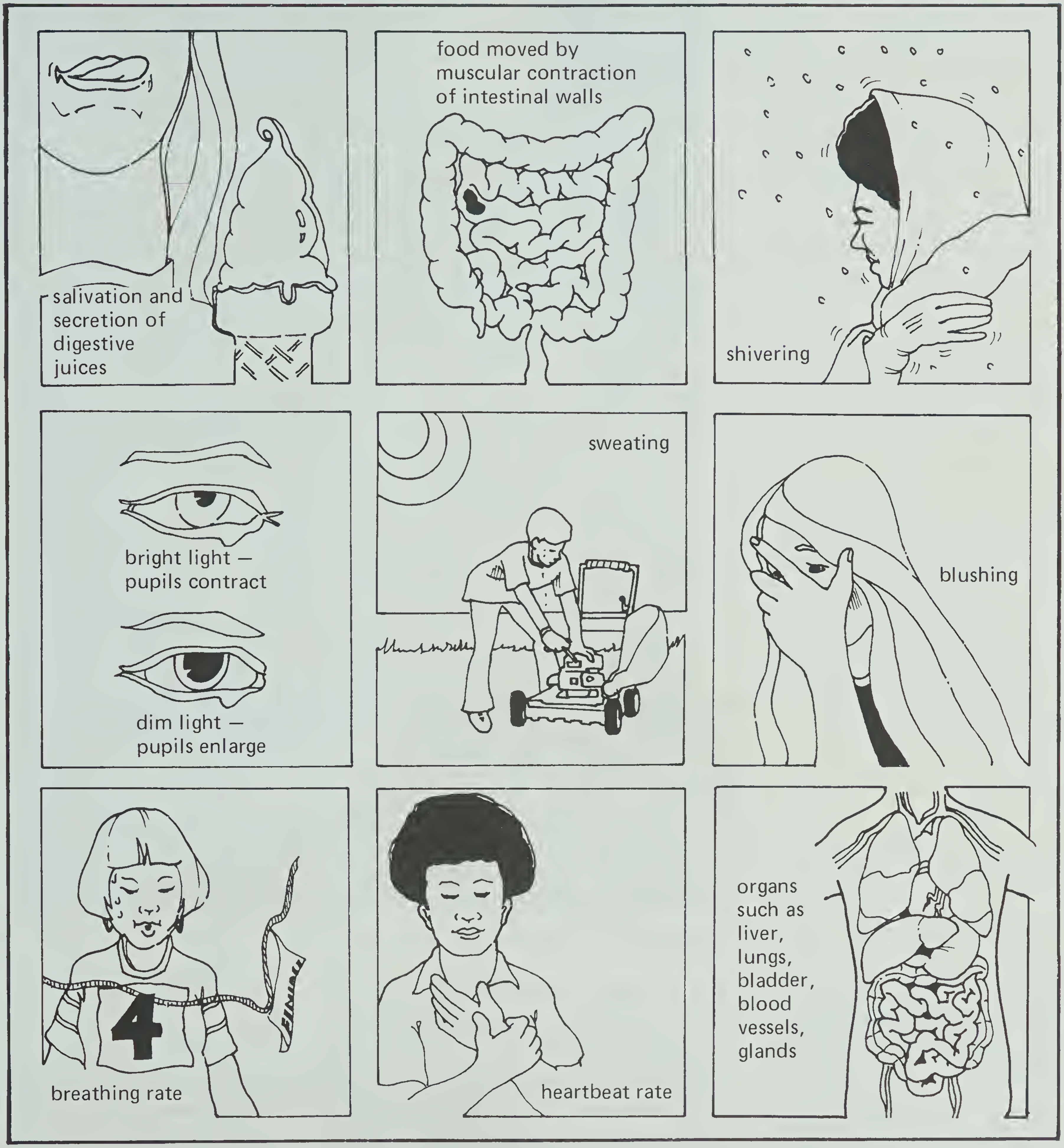


Figure 8-1

8-3. B, C, D, F, G, J

☆ 8-3. Which of the following body processes or functions are controlled by the autonomic part of the nervous system?

A. Chewing gum
B. Secreting digestive juices
C. Beating of heart
D. Moving intestinal muscles
E. Walking up stairs
F. Blushing
G. Increasing pupil size in dim light
H. Talking to a friend
I. Pointing at a passing car
J. Perspiring in hot weather
K. Thinking about school

Goose bumps may seem useless to you. As a human being, you don't have much body hair. Most other mammals, however, have a lot of hair. And for them, this response is important. Cold temperatures cause tiny muscles at the bottom of each hair to contract, pulling the hairs into an upright position. This "thickens" the animal's fur and helps keep it warm. Look at Figure 8-2 below.

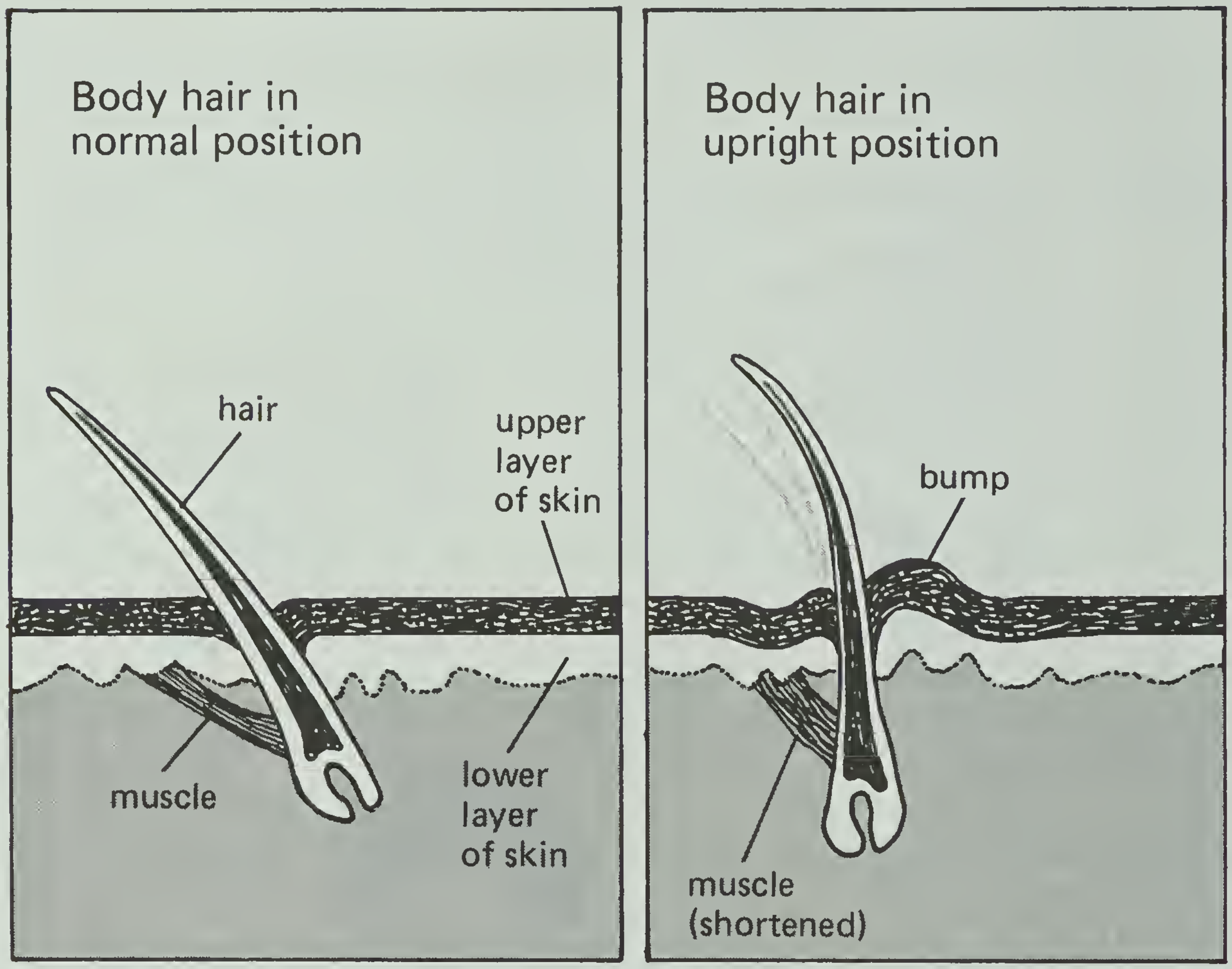


Figure 8-2

8-4. Body hairs stand upright. [The process is characteristic of homoiothermic (warm-blooded) animals generally.]

● 8-4. According to Figure 8-2 above, what happens to cause goose bumps to appear on a mammal's skin?

The hypothalamus in the brain stem is the central "headquarters" for the autonomic nervous system.

Figure 8-3 (page 33) will help you understand how this and other autonomic reflexes are controlled. It shows the main parts of the autonomic system. Study it carefully, and then answer Questions 8-5 through 8-7 on page 33.

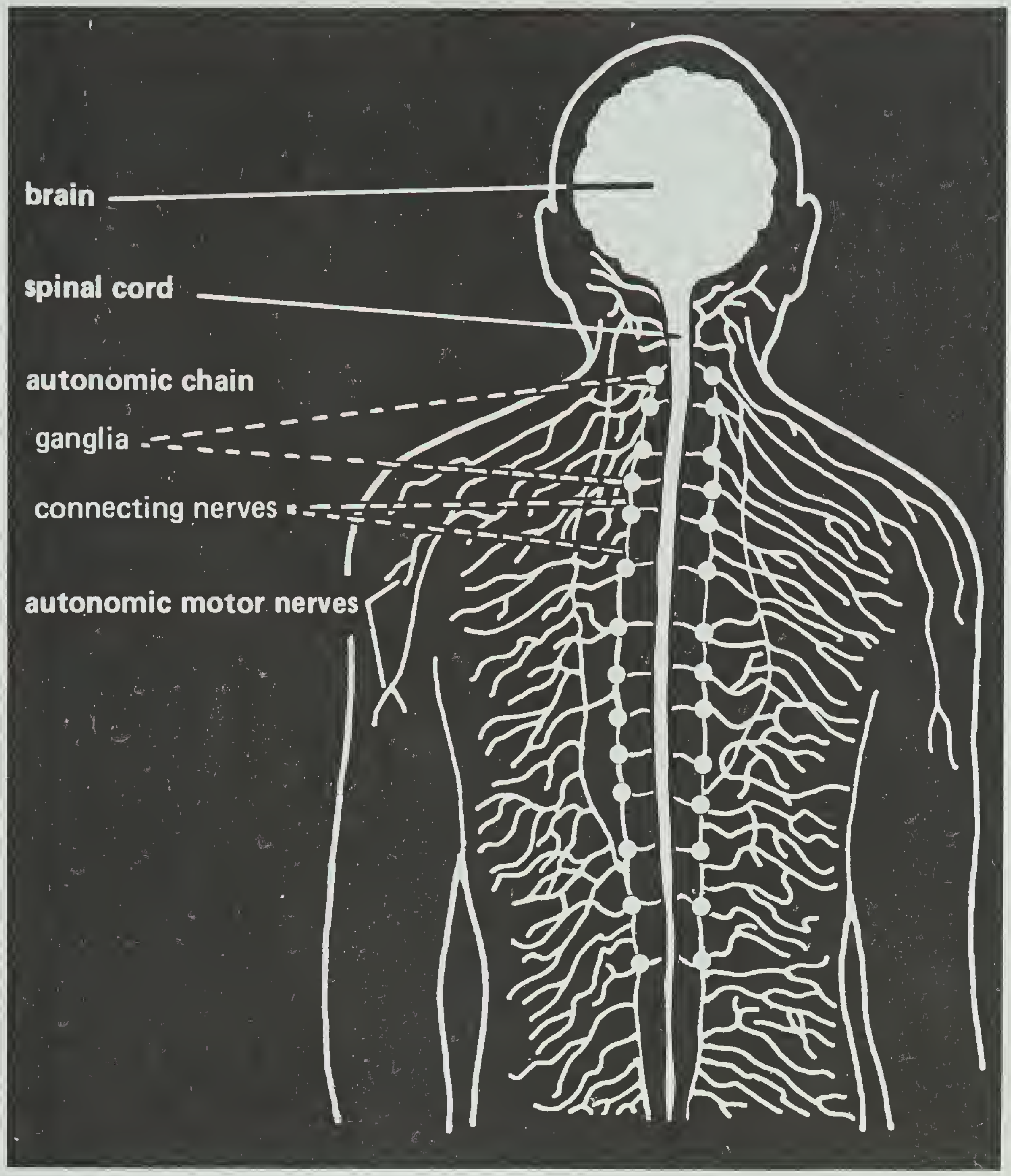


Figure 8-3

1. **Brain** monitors body functions and controls all autonomic reflexes by means of autonomic centers, which receive and send nerve messages. Some nerve messages go directly to and from the brain by way of nerves in the head. Others go by way of the spinal cord.

2. **Spinal cord** carries most nerve messages to and from the brain.

3. **Autonomic chain** is made up of ganglia — knotlike groups of nerve cell bodies along the outside of the spinal cord — and nerve fibers that connect the ganglia with the spinal cord.

4. **Autonomic motor nerves** carry messages from ganglia to various organs, such as eyes, nose, lungs, heart, liver, stomach, adrenals, small intestine, bladder, and sweat glands, to body-hair muscles and to the muscles of blood vessels.

● 8-5. What are ganglia? Where are they found?

● 8-6. Why is part of the autonomic system called a *chain*?

☆ **8-7. What role does the brain play in controlling autonomic reflexes?**

The brain is constantly receiving messages from sensory nerve endings throughout the body. These messages allow the brain to monitor body processes at all times and make any necessary changes. Figure 8-4 (page 34) shows how motor nerve messages flow through the autonomic part of the nervous system to cause a change.

8-5. Knotlike groups of nerve cell bodies; along the outside of the spinal cord

8-6. Connecting nerves and ganglia are linked along the spinal cord like a chain.

8-7. It receives and processes sensory messages from organs, then sends controlling motor nerve messages to the organs by means of the autonomic part of the nervous system.

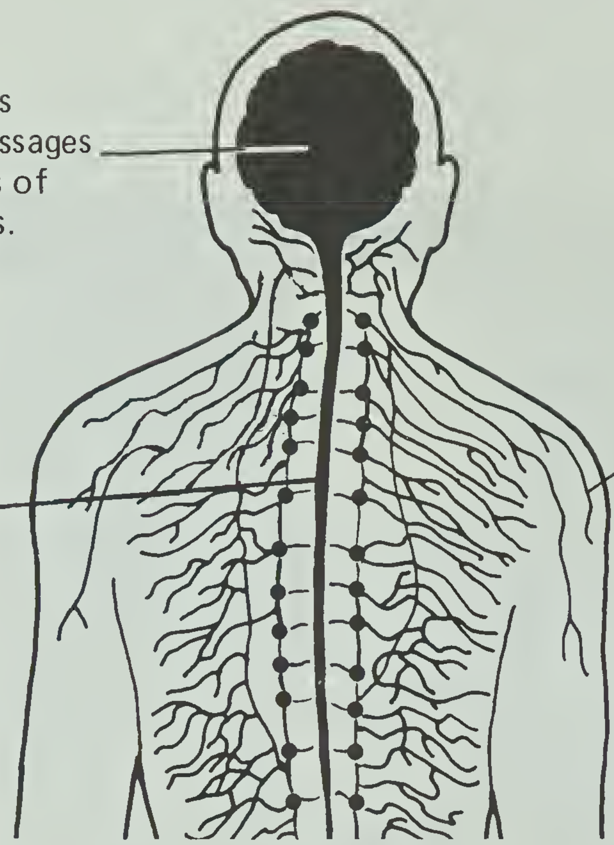


Figure 8-4

8-8. From the brain directly or through the spinal cord, through the autonomic chain and autonomic motor nerves to organs and glands

☆ **8-8. Some autonomic motor nerve messages go from the brain to body organs and glands. What is the nerve pathway?**

8-9. E, B, A, D, C

● 8-9. List these steps in the order in which they occur when food enters your stomach and digestion begins.

A. Messages travel through autonomic chain.
B. Autonomic digestion center sends messages down spinal cord.
C. Messages cause digestion to begin.
D. Messages travel on autonomic motor nerves to stomach.
E. Brain receives sensory messages that food is present in stomach.

ACTIVITY EMPHASIS: The mechanisms of hearing, taste, and smell are described and explained.

MATERIALS PER STUDENT LAB GROUP: See tables in "Materials and Equipment" in ATE front matter. See "Advance Preparations" in ATE front matter.

ACTIVITY 9: HEARING, TASTE, AND SMELL

Stimuli, or bits of information, are all around you. But before you can be aware of stimuli, they have to be changed into forms your brain can understand – nerve messages. Your sense of hearing changes sound vibrations into nerve messages. Your senses of taste and smell change chemical stimuli into nerve messages.

9-1. Nerve messages

● 9-1. What does your sense of vision change light stimuli into?

A model of the ear would be very helpful to students doing this activity.

In this activity, you'll look at how stimuli are changed into nerve messages by three of your senses – hearing, taste, and smell.

The human ear is divided into three sections: the outer ear, the middle ear, and inner ear. Study Figure 9-1 (page 35) as you read about the various parts of these sections and what they do. If a model of the ear is available, use it, too.

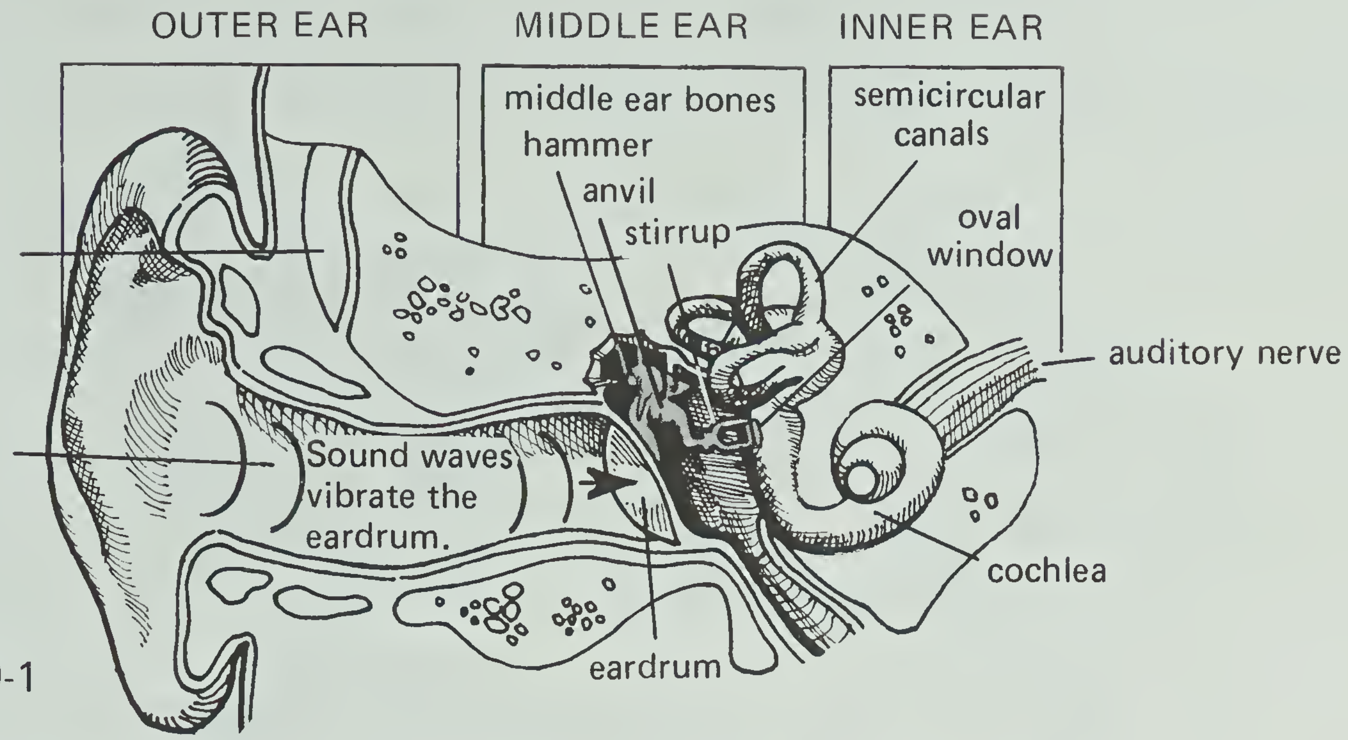


Figure 9-1

The outer ear receives sound waves. It channels the vibrations down the ear canal to the eardrum. The eardrum is a thin membrane stretched over the end of the ear canal. When sound waves strike the eardrum, it vibrates.

☆ **9-2. What is the role of the eardrum?**

9-2. It vibrates when struck by sound waves.

The three bones of the middle ear form a "bridge" to transmit the vibrations from the eardrum to the oval window of the inner ear. Look at Figure 9-2 below. Those bones also amplify the vibrations about three times. That is, they make the vibrations three times stronger.

The stirrup (stapes) is the smallest bone in the human body.

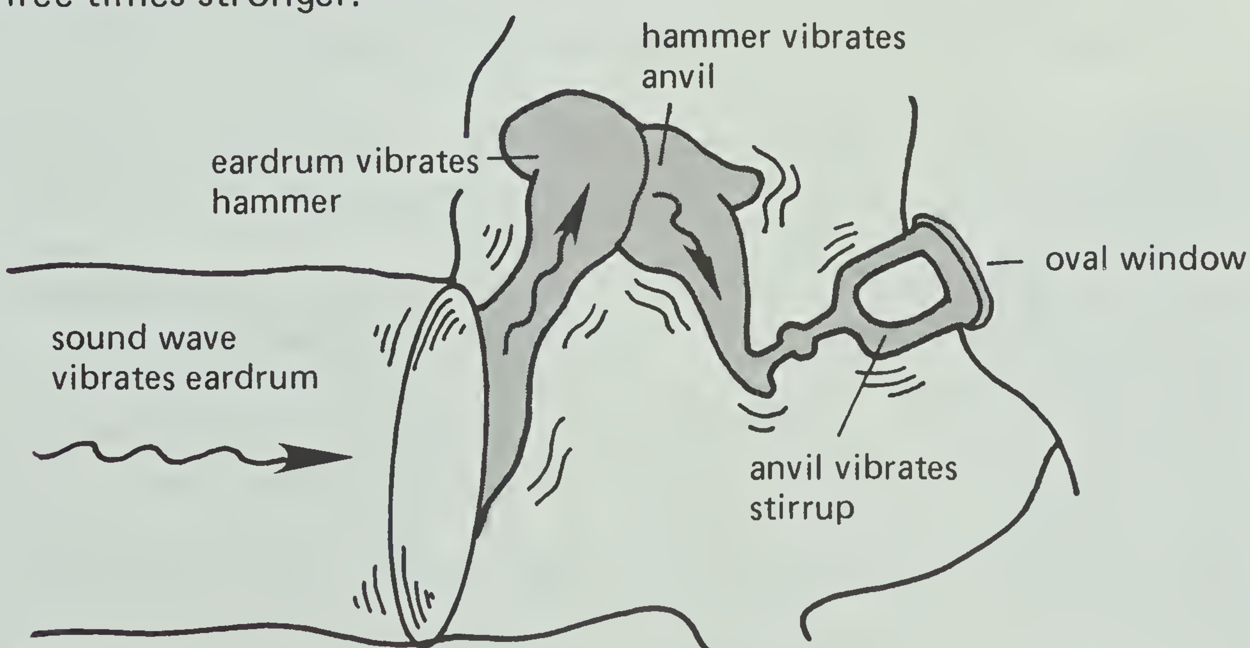


Figure 9-2

☆ **9-3. What are the two roles of the middle ear bones?**

9-3. To carry vibrations to the inner ear and to amplify the vibrations

The oval window is a membrane about one-thirtieth the size of the eardrum. This size difference allows the oval window to amplify the vibrations from the eardrum about thirty times.

9-4. Middle ear bones and oval window

☆ **9-4. What parts of the ear amplify vibrations?**

The inner ear contains two main fluid-filled structures — the semicircular canals and the cochlea [KO-klee-ah]. The semicircuiar canals are related to your sense of balance, the cochlea to your hearing. When the stirrup moves the oval window, vibrations are set up in the fluid in the cochlea. The vibrations stimulate tiny sensory cells in the organ of Corti. These cells are attached to sensory nerve endings, which change the vibrations into nerve messages. The nerve messages are sent along the auditory (hearing) nerves to the brain stem. Look at Figure 9-3 below.

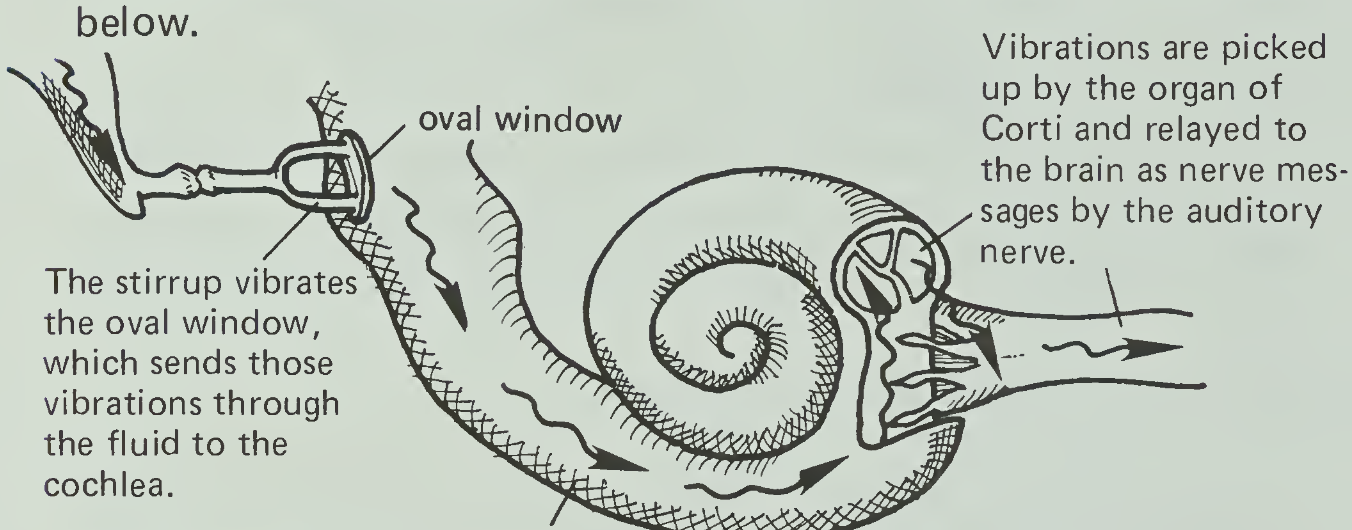


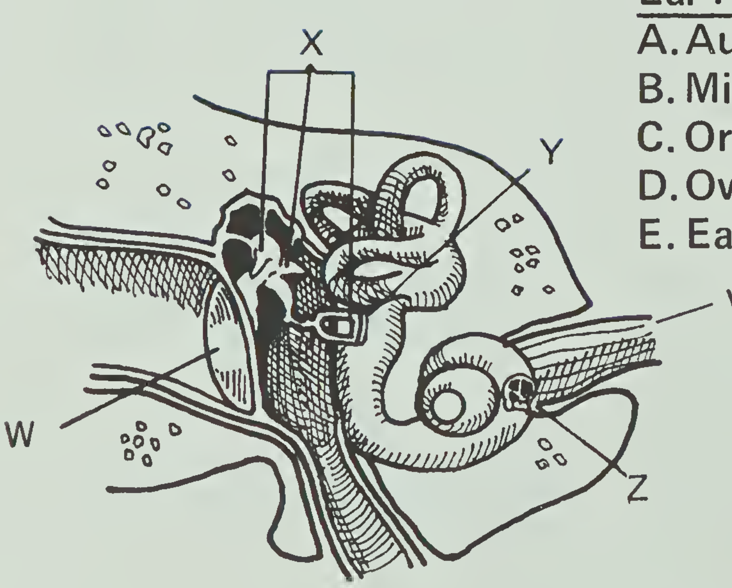
Figure 9-3

From the brain stem the nerve messages go to the auditory area of the cerebrum. There they are decoded and interpreted as sound — noise or music, jackhammer or guitar.

9-5. A2V, B4X, C5Z, D1Y, E3W

☆ **9-5. Match each ear part two ways — first with its role in hearing and then with the letter in the diagram below.**

Ear Part	Role
A. Auditory nerve	1. amplifies vibrations to inner ear about thirty times
B. Middle ear bones	2. carries nerve messages from organ of Corti to brain stem
C. Organ of Corti	3. vibrates when sound in ear canal reaches it
D. Oval window	4. transmit vibrations from eardrum to inner ear
E. Eardrum	5. contains sensory cells attached to sensory nerve endings



Taste is a chemical sense. Molecules in the food you eat and drink provide taste stimuli. Most of your sensors for taste are located on your tongue. Look at your own tongue in a mirror, and notice the tiny bumps called *papillae* [puh-PILL-ee]. Look at Figure 9-4 below.

Have a mirror available for students to use.

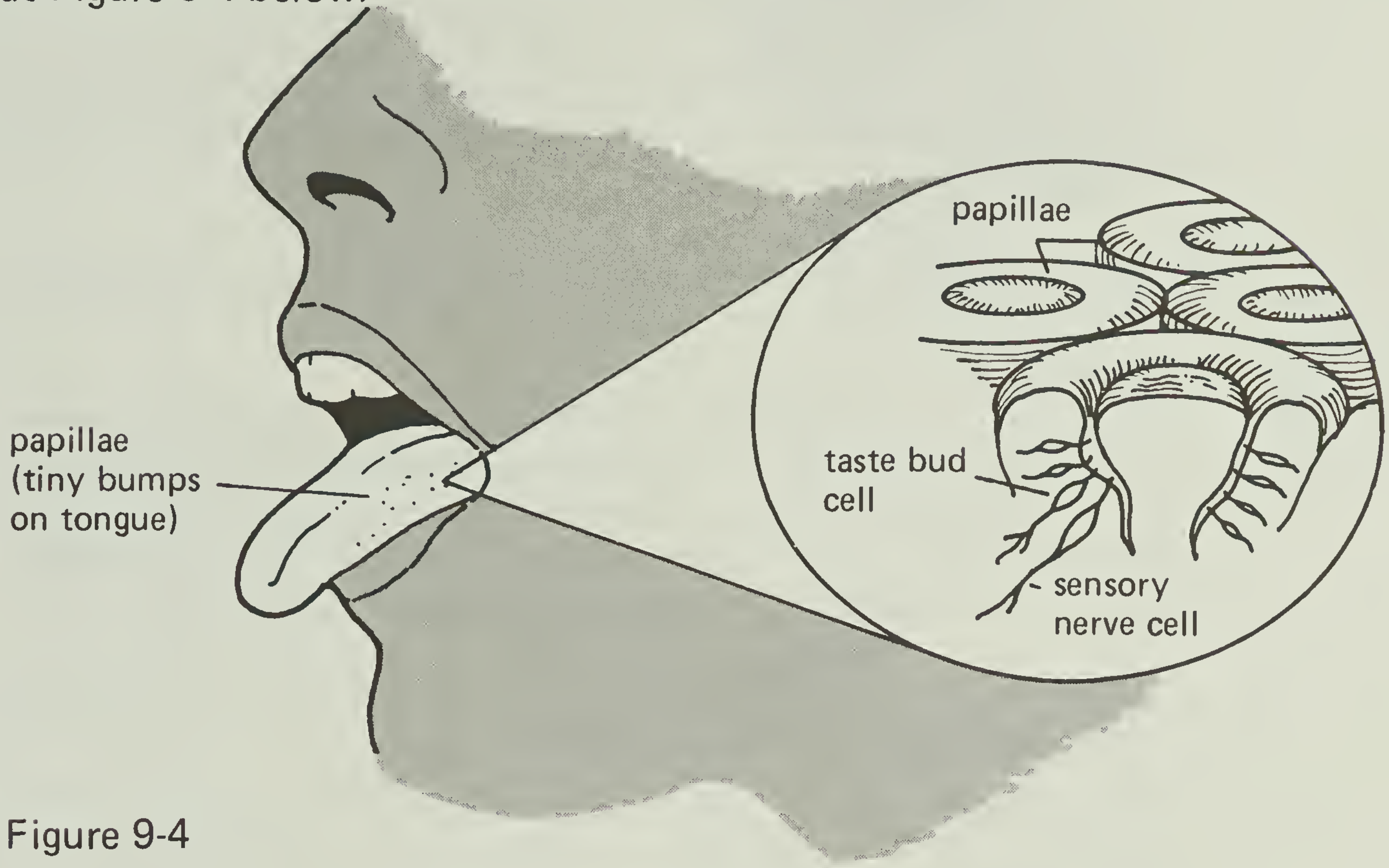


Figure 9-4

Inside the papillae are taste bud cells, which contain sensory nerve cells. Each taste bud cell has a tiny, hairlike projection. This seems to be where the chemical sensing takes place. When the taste bud cells are stimulated, sensory nerve endings change the stimuli into nerve messages. Sensory nerves then send the messages to the brain.

Try a tasteful investigation. You'll need a partner and the following materials.

paper towel
sugar
spatula or wood splint
watch or clock with second hand

A. Dry the upper surface of your tongue with the paper towel.

B. Have your partner use the spatula to place several crystals of sugar on the front part of your tongue.

C. Time how long it takes you to notice a sweet taste.

Were you surprised? As long as your tongue stays dry, you won't notice a sweet taste. Substances must be dissolved before the taste cells can sense them.

9-6. The dissolved substance stimulates sensory nerve endings in the taste bud cells, which change the stimuli into sensory nerve messages. Sensory nerves then send the messages to the brain.

☆ **9-6. Describe how the sense of taste responds to a substance such as sugar or salt.**

You can tell the difference among four basic tastes: sweet, sour, salty, and bitter. The taste cells for each taste are not evenly distributed over the tongue. You can get an idea of the location of the tongue's general taste areas by doing an investigation. You'll need a partner and the following materials.

paper towel
4 cotton swabs
salty solution
sweet solution
sour solution
bitter solution
cup of water

LOCATION	SWEET	SALTY	SOUR	BITTER
Tip of tongue				
Back of tongue				
Sides of tongue				

A. Make a table similar to this one in your notebook.

B. Rinse your mouth thoroughly with the water. Then dry your tongue with the paper towel.

C. Have your partner apply a small amount of the sweet solution to the tip of your tongue with a cotton swab. Put an *X* in your table if you can taste the solution, an *O* if you can't.

D. Have your partner apply the sweet solution to the back and then the sides of your tongue. Record your results after each test, and then decide where you tasted the solution the best.

E. Repeat Steps B through D for the other three solutions. Use a new cotton swab for each solution.

9-7. [Answers will vary but should give results similar to Figure 9-5 below.]

9-8. They are combinations of the four basic tastes and are affected by odor, texture, temperature, and smell.

- 9-7. Where did you taste each solution the best?

If you're like most people, you probably tasted sweet the best at the tip of your tongue. Salty and sour were probably tasted at the sides and bitter at the back. Look at Figure 9-5 at the right.

Most tastes you sense are combinations of the four basic tastes. Taste is also affected by odor, temperature, and texture. Anyone who has ever eaten a warm, juicy hamburger will agree to that. And if you've ever had a head cold, you know what happens to taste when you can't smell.

- 9-8. Why are most tastes hard to describe?

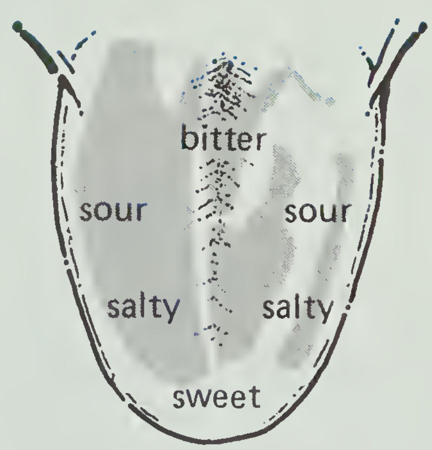


Figure 9-5

Your nose responds to chemical stimuli too. Smell results from the chemical stimulation of sensory nerve endings in the nose. Look at Figure 9-6 (page 40).

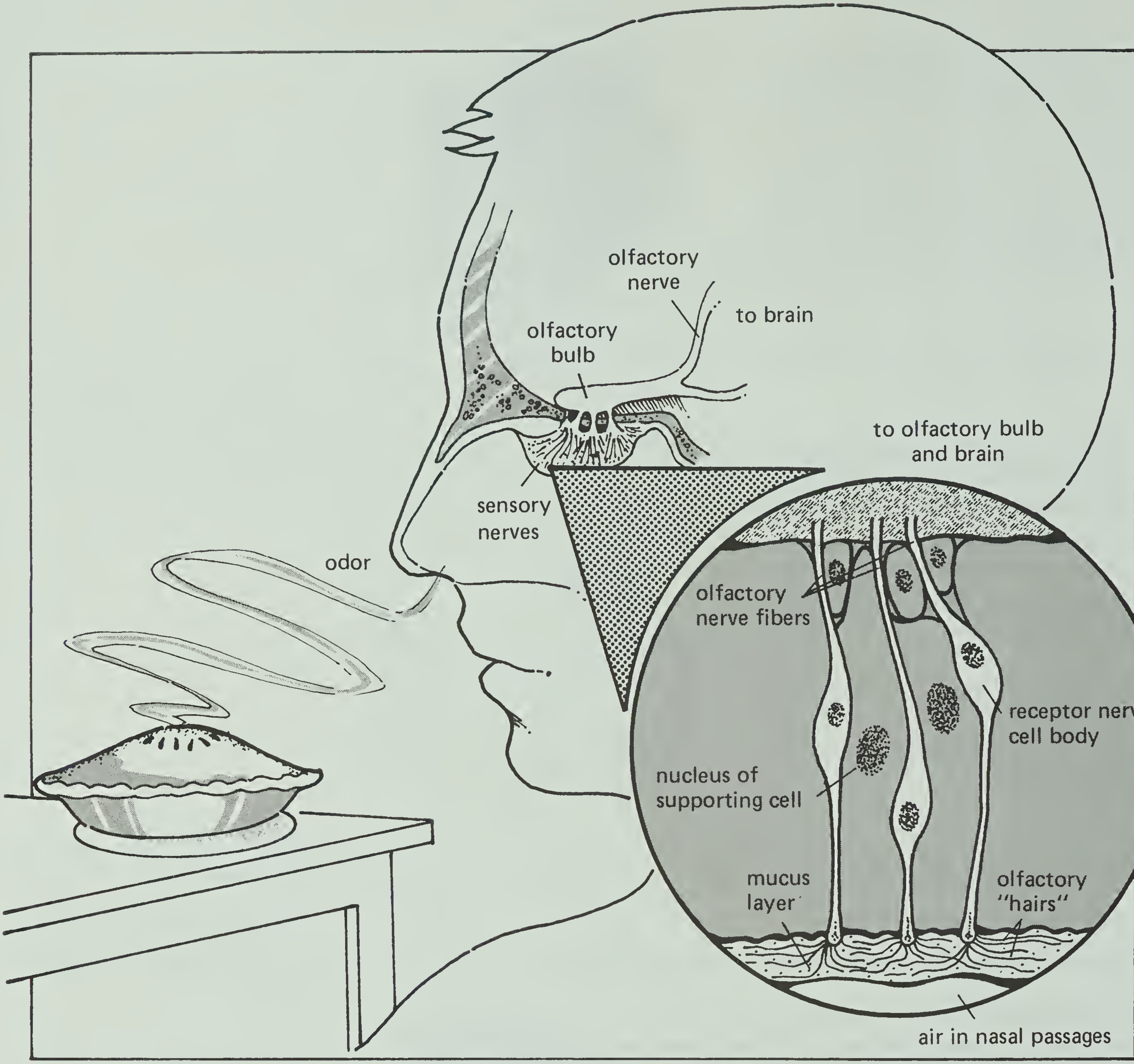


Figure 9-6

9-9. Molecules in inhaled air stimulate olfactory hairs attached to olfactory nerve cells, which change the stimuli into sensory nerve messages. The olfactory nerve sends the nerve messages to the brain.

Each nostril has three layers separated by bony tissue. The olfactory (smell) nerve cells are in the top layer. Several tiny olfactory hairs reach from each nerve cell into a layer of mucus. When molecules in inhaled air stimulate these hairs, the nerve cells change the stimuli into sensory nerve messages. The olfactory nerve sends the nerve messages through the olfactory bulb to the brain.

☆ 9-9. How does the nose detect odors?

ACTIVITY 10: DRUGS AND THE NERVOUS SYSTEM

ACTIVITY EMPHASIS: The effects on the human nervous system of the following commonly used psychoactive drugs are described and explained: amphetamines, caffeine, cocaine, ethyl alcohol, heroin, LSD, marijuana, and nicotine.

MATERIALS PER STUDENT LAB GROUP: See tables in "Materials and Equipment" in ATE front matter. See "Advance Preparations" in ATE front matter.

Throughout recorded history, some members of every human society have used substances that change the body's chemical activities. Some uses were approved by these societies, and some weren't. This is true today, too, especially about the use of psychoactive drugs — chemicals that affect the nervous system.

- 10-1. What is a psychoactive drug?

People who use psychoactive drugs give many different reasons for doing so. Look at Figure 10-1 below.

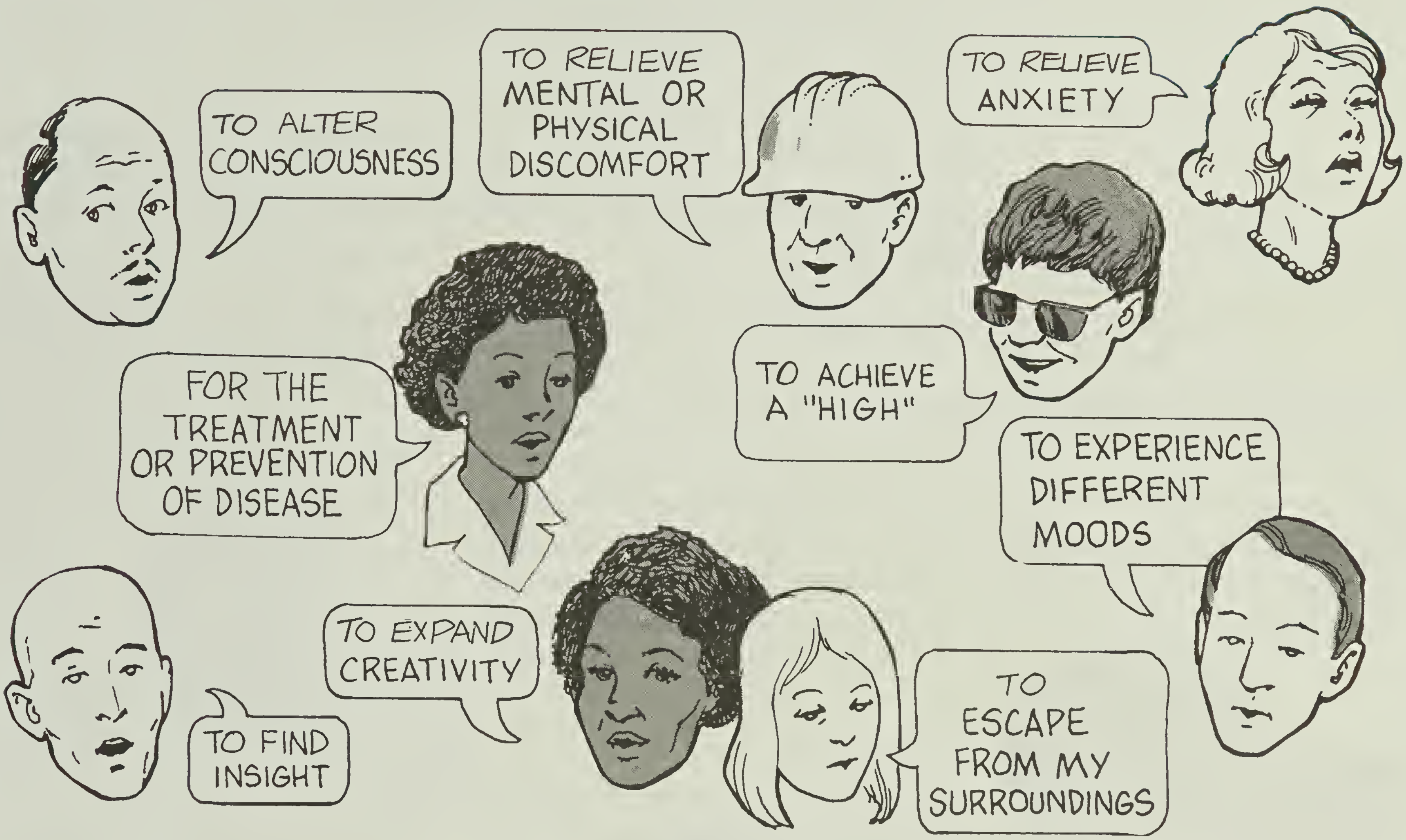


Figure 10-1

10-1. A chemical that affects the nervous system

- 10-2. Which of the uses of psychoactive drugs given in Figure 10-1 above are generally not approved by society today?

10-2. [Answers will vary; this might be a good group-discussion question.]

In the first part of this activity, you'll look at the physical effects produced by some common psychoactive drugs. Of course, you won't study these effects on yourself or a classmate. Instead, you'll see how three of these drugs affect the heartbeat of an animal. (The heart is a muscle, not a nerve. But it has nerve cells in it that react to drugs.)

See "Advance Preparations" for possible substitutes for the *Daphnia*.

You might want to have all your students do this investigation so that you can pool the data.

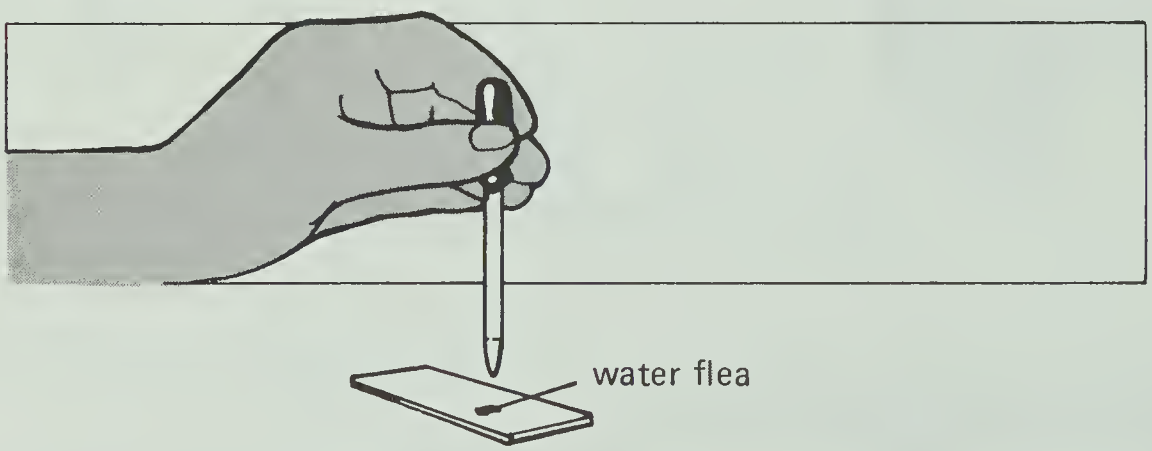
A convenient animal to use is the tiny water flea known as *Daphnia*. It's so transparent that you can see its heart. You'll need a partner and the following materials.

Daphnia culture
microscope
microscope slide
coverslip
medicine dropper
paper towels
watch or clock with second hand
ethyl alcohol solution in dropping bottle
caffeine solution in dropping bottle
nicotine solution in dropping bottle
cotton

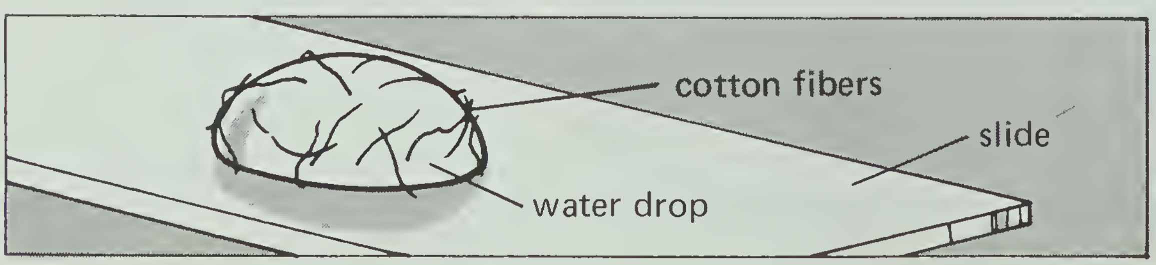
If you're not sure how to use a microscope, read "Resource Unit 3: Using a Microscope" now. And if you don't know how to figure an average, read "Resource Unit 1: Averaging." Then begin Step A.

TRIAL	NUMBER OF *DAPHNIA* HEARTBEATS IN 10 SECONDS					
	Normal	Ethyl Alcohol	Normal	Caffeine	Normal	Nicotine
1						
2						
3						
Total						
Average						

A. In your notebook, make a table like this one.

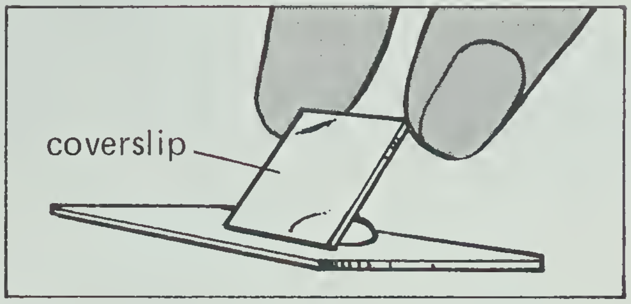


B. Using the dropper, pick up a water flea from the culture. Put it on the microscope slide.



C. Put a few cotton fibers into the water so that the water flea won't be able to jump around.

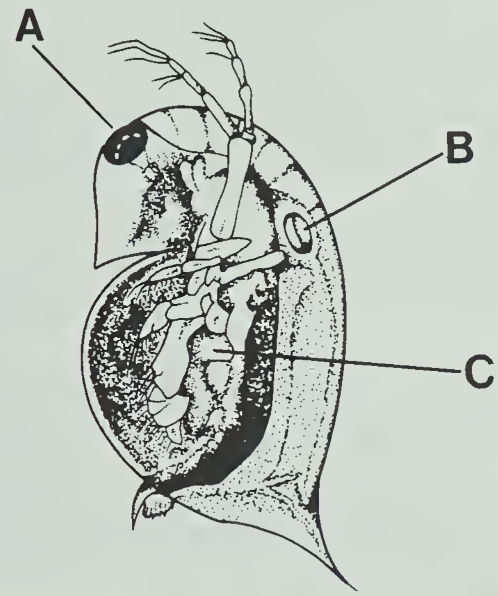
D. Cover the water with the coverslip.



E. Turn the low-power objective of the microscope into position. Put the slide on the microscope stage. Focus the microscope. You should see the water flea. If your microscope has a light, be sure to turn the light off when you are not looking through the microscope.

● 10-3. Compare your flea with the diagram in Figure 10-2 below. Which is the water flea's heart – A, B, or C? How can you tell?

10-3. B; you can see it beating and pumping "blood" (a clear fluid).

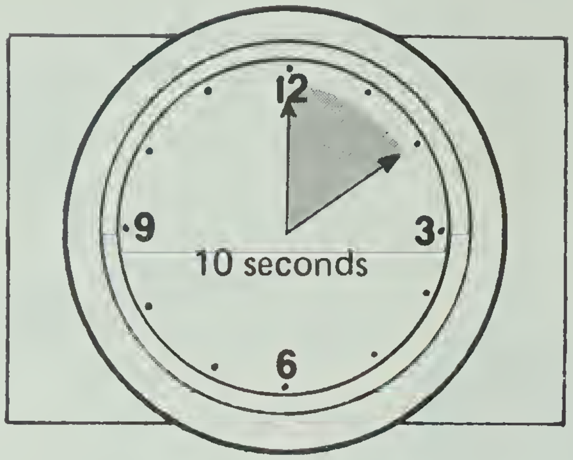


There are many moving parts in the water flea's body. The heart is near the surface of the back side of its body, almost directly behind its eyes.

Figure 10-2

F. Now you'll measure the water flea's heart rate. It is quite fast. The best way to do this is to tap the table with a pencil, eraser down, matching the rate of tapping to the heartbeat and timing it.

An alternative you might suggest is tapping with the point of the pencil on a piece of paper, then counting the dots made during a measured time interval.

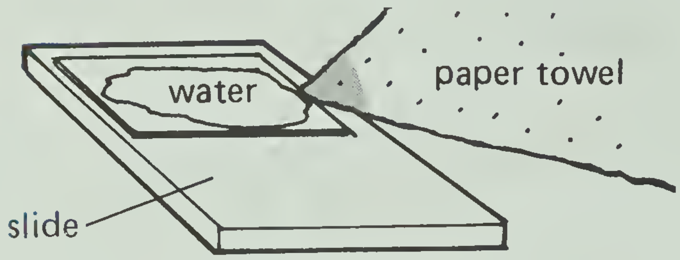


G. Have your partner keep time for you by counting the number of heartbeats (taps of the pencil) that occurs in 10 seconds. Record the results in your table. Do this three times, and average your results.

10-4. [Answers will vary. The range for a healthy flea at 20°C is 45 to 70 beats in 10 seconds. This may be too fast for some students to count accurately.]

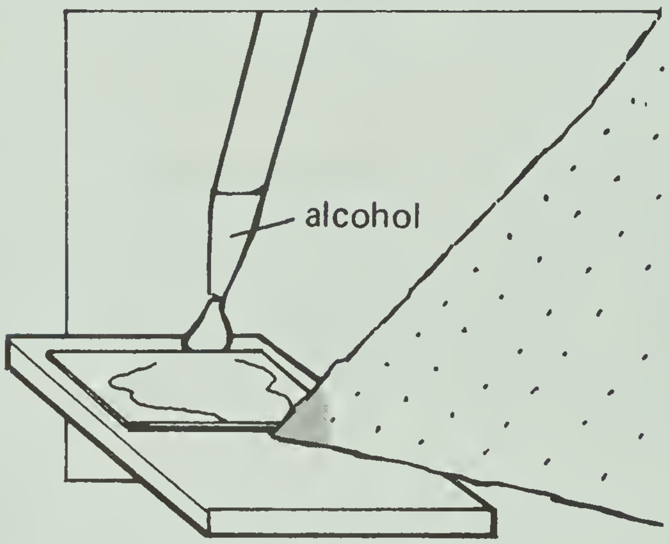
● 10-4. What is the average number of heartbeats in ten seconds?

Now, let's see how the heart rate is affected by a psychoactive drug. Remember, this will give you an idea of how the drug is affecting the water flea's nervous system.



H. With a paper towel, draw any excess water from the slide.

Though alcohol slows down a flea's heart rate, it can speed up the heart rate of mammals, including humans; the speed-up may cease and become a slow down at some higher alcoholic intake level.



I. With the dropper, place one drop of ethyl alcohol solution at the edge of the cover-slip.

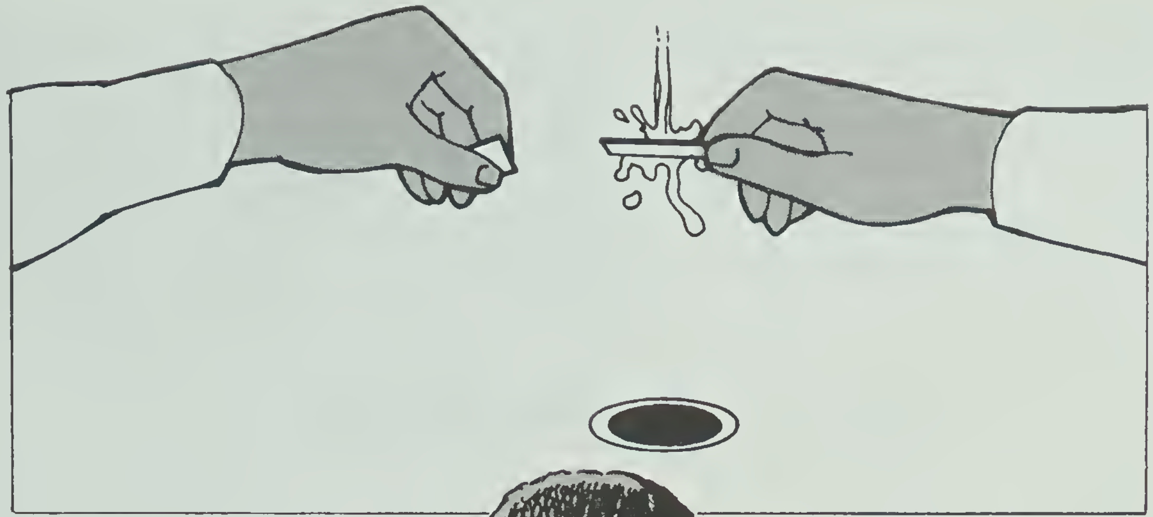
J. On the opposite side of the slip, touch a piece of paper towel to the liquid to draw the alcohol solution across the slide.

K. Examine the water flea, and count its heart rate for 10 seconds, again with your partner's help. Record the results in your table. Do this three times. Find the average.

10-5. [Answers will vary; it slowed it down and may have stopped it.]

● 10-5. How did the ethyl alcohol affect the flea's heartbeat rate?

L. Thoroughly rinse and dry the slide and coverslip. Wash the "used" water flea down the drain.



M. Repeat Steps B through D and G through L first with the caffeine solution and then with the nicotine solution. Be sure to record your results in your table.

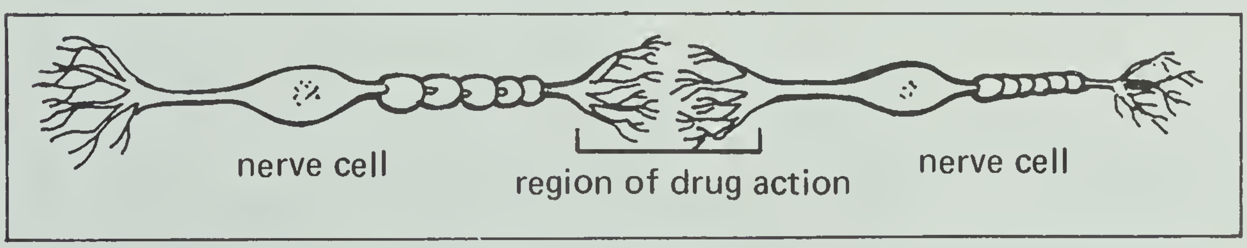
● 10-6. Which drug or drugs stimulated (speeded up) the water flea's heart rate?

10-6. Caffeine and nicotine (usually)

● 10-7. Which drug or drugs depressed (slowed down) the heart rate?

10-7. Ethyl alcohol

Most psychoactive drugs are a lot like the body's own nerve chemicals. They act on nerve cells by altering the chemical processes that go on between nerve cells.

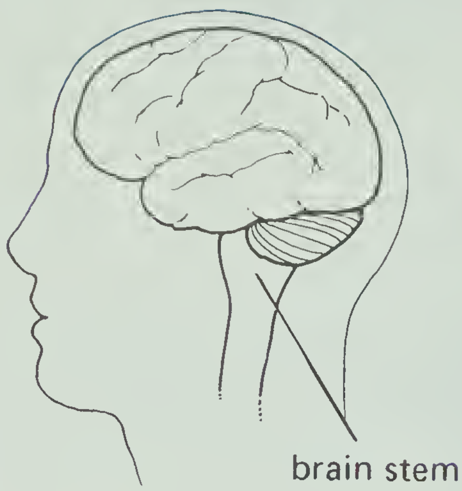


Such drugs affect the flow of nerve messages throughout the nervous system. When they affect nerve cells in the brain, they cause changes in behavior.

☆ **10-8. How do psychoactive drugs cause behavior changes?**

10-8. By acting on nerve cells in parts of the brain

The rate of brain-cell death seems to be accelerated by alcohol consumption.

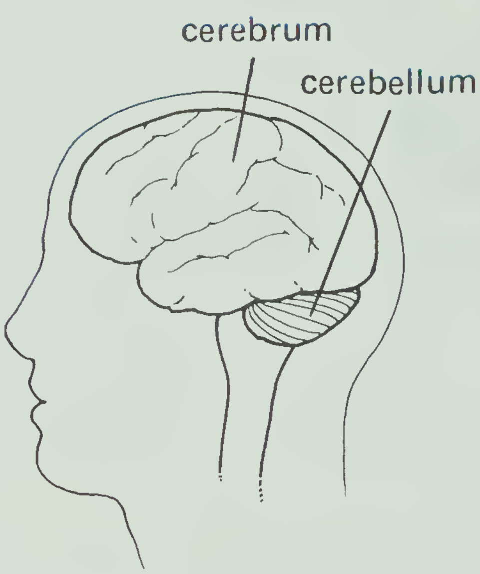


One of the psychoactive drugs you tested was ethyl alcohol — the same substance found in beer, wine, and liquor. Ethyl alcohol is called a *depressant* because it slows down behavior, causing relaxation and sleep. Other depressant drugs include barbiturates (such as phenobarbital), methaqualone (Quaalude), general anesthetics (such as ether), and some antianxiety agents (such as Miltown). The opiates (opium, morphine, and heroin) are extremely powerful depressants.

Depressants affect the nerve cells throughout the brain. The more of the drug present, the greater its effects. One brain area affected is the brain stem, one of the main controllers of the central nervous system. The brain stem contains centers that control breathing, blood pressure, heart rate, strength of heart contraction, digestion, and alertness (sleeping and waking).

10-9. They are all depressants that slow the action of the alertness center.

☆ **10-9. Explain why a person may feel sleepy after taking an opiate or barbiturate or drinking alcohol.**



But the effects of alcohol and other depressants are not limited to the life processes listed above.

The brain stem also controls the flow of information in and out of the cerebrum and cerebellum. The cerebrum contains centers for controlling thought, vision, speech, hearing, perception, and motion. The cerebellum coordinates motor actions so that muscles contract and relax correctly.

Scientists think that small amounts of alcohol depress the action of the brain stem, releasing some of its control over the cerebrum. After one or two drinks, a person may feel lively and talkative. But after several drinks, the cerebrum, cerebellum, and brain stem are all affected, and typical drunken behavior is observed. That's the reason it's dangerous and illegal to drive after the amount of alcohol in the blood reaches a certain level.

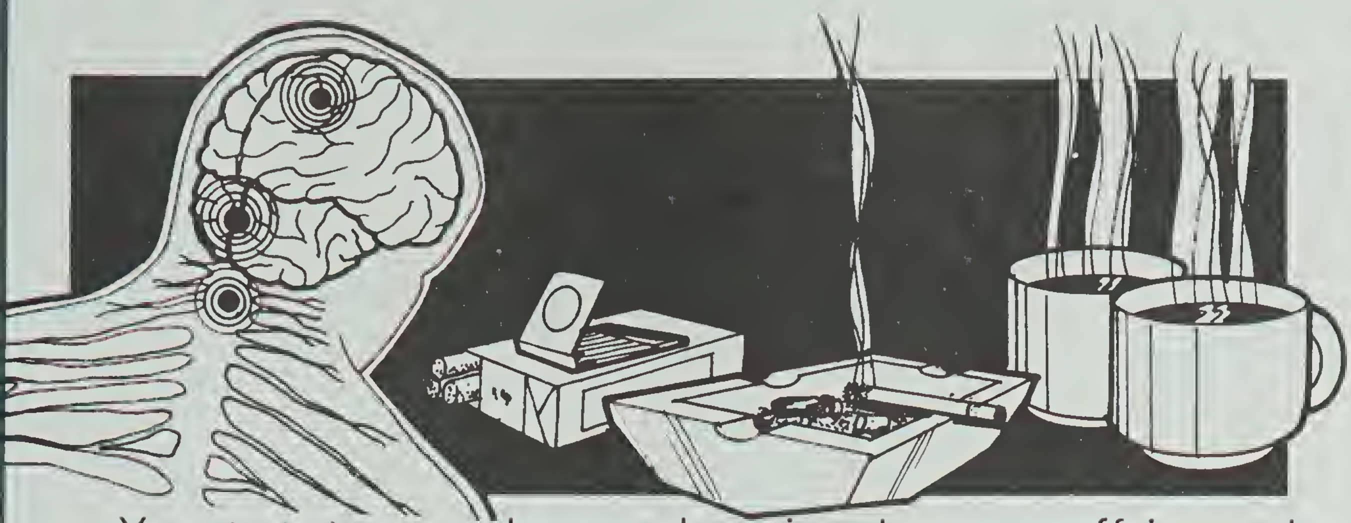
10-10. Alcohol depresses control of the body by the cerebrum and cerebellum.

☆ **10-10. Why does a person who is drunk stagger and have slurred speech?**

A person who drinks enough alcohol to totally depress the breathing control center in the brain stem will stop breathing and die. An overdose of any depressant drug can cause death in the same way. And the effects of depressant drugs add to each other. People who take other depressants along with alcohol are risking their lives.

10-11. The action of the breathing control center in the brain stem is totally depressed, and breathing stops.

☆ **10-11. How does an overdose of one or more depressants cause death?**



You tested two other psychoactive drugs — caffeine and nicotine. Both of these drugs are called *stimulants*. They stimulate the activity of the cerebrum and — in stronger doses — of the brain stem. As many smokers know, some stimulants can be habit-forming. They can also have undesirable side effects or "rebound" effects.

Figure 10-3 on pages 48 and 49 summarizes information about various psychoactive drugs. Use it to answer Questions 10-12 through 10-16 below.

• 10-12. Like alcohol, heroin depresses certain parts of the brain. Which part does it stimulate? How does it affect the perception of pain?

10-12. Heroin stimulates the vomiting center. It alters perceptions of painful stimuli.

• 10-13. The amphetamines and cocaine are both stimulants. Cocaine acts in one important way that the amphetamines don't. What is it?

10-13. Cocaine also blocks nerve messages.

• 10-14. Why might a person have trouble falling asleep after drinking a cup of coffee?

10-14. Coffee contains caffeine, which is a stimulant.

☆ **10-15. Match each psychoactive drug with its action on the brain. (Answers may be used more than once.)**

Psychoactive Drug	Action on Brain
A. Heroin	1. depresses brain stem activity
B. Amphetamine	2. stimulates brain stem and cerebrum activity
C. Cocaine	3. acts like a nerve-chemical substance
D. Caffeine	4. blocks nerve messages
E. Nicotine	5. interferes with nerve message transmission
F. LSD	6. acts only on certain nerve cells
G. Marijuana	7. alters pain perception
	8. not understood

10-15. A1, 7; B2, 3, 6; C2, 3, 4, 6, 7; D2, 6; F5, G8

☆ **10-16. What action on the brain do all stimulants have in common?**

10-16. They stimulate brain stem and cerebrum activity.

DRUG (Slang names)	TYPE OF DRUG	ACTION(S) ON BRAIN	EFFECTS	OTHER INFORMATION
Amphetamines (''speed,'' ''uppers,'' ''turnarounds'')	stimulant	stimulates brain activity by acting like nerve-chemical substances on certain neurons in both brain stem and cerebrum	increased alertness and excitement; increased breathing rate; wakefulness (insomnia); increased motor activity, heart rate, blood pressure; loss of appetite	High doses cause mental-disease symptoms — confused behavior, irritation, fear, suspicion, delusions, aggressiveness. Rebound effects occur when heavy drug use is stopped — sleep, depression, hunger, lethargy; suicide possible.
Caffeine	stimulant	stimulates activity of certain neurons in cerebrum and then brain stem; also stimulates heart, blood vessels, and other organs	increased alertness, clearer thought; wakefulness; restlessness; may interfere with sleep; nausea and vomiting; increased heart rate and fluttery heartbeat; abdominal pain	Found in coffee, tea, and cola drinks, caffeine is the most widely used stimulant; it is a weaker stimulant than cocaine or amphetamines. Depression is possible when drug ''wears off.'' At low doses, stimulation of cerebrum occurs without effects on brain stem.
Cocaine (''coke,'' ''snow,'' ''snort'')	stimulant	see *Amphetamines*; also blocks nerve messages	see *Amphetamines*; also anesthesia (nerve-deadening)	It is a very fast and potent drug; rebound and high-dose effects are similar to amphetamines; it can have bad effects on membranes of nose when chronically ''sniffed.''
Nicotine	stimulant	stimulates neurons in brain sensitive to one type of nerve chemical; stimulates breathing and vomiting centers in brain stem; also affects nerves coming from muscles	tremors; shaking, vomiting; relaxation; cramping and diarrhea	It is inhaled in cigarette smoke; after caffeine, it's the next most widely used stimulant. It has bad effects on lungs and heart, and can cause narrowing of blood vessels.

Figure 10-3 (continued on page 49)

DRUG (Slang names)	TYPE OF DRUG	ACTION(S) ON BRAIN	EFFECTS	OTHER INFORMATION
Alcohol ("booze")	depressant	depresses nerve cells in brain stem and, in larger amounts, nerve cells in cerebrum and cerebellum	decreased alertness; less sensitivity to fatigue, pain; in larger doses, causes drowsiness, loss of motor functions; can overdose to coma, death	Technically, it's a poison but may have some positive qualities in low dosages. Drunk drivers are involved in half of nation's yearly auto fatalities. It's addictive; alcoholism is epidemic in many countries.
LSD ("acid")	psychedelic	seems to interfere with impulse transmission; somehow alters sensitivity of brain's arousal center to incoming information	changes in mood and emotion; perceptions of stimuli altered — hallucinations	It has effects at very low doses; "flashbacks" (reexperiencing of earlier effects). It may cause permanent disorganization of personality. Psilocybin acts in same ways.
Marijuana ("pot," "dope")	mixed depressant-stimulant	unknown	increase in pulse rate; bloodshot eyes; nausea, dizziness, mouth dryness; sleepiness; feeling of well-being	Studies show marijuana affects driving ability. Personality changes have also been found; research continues.
Heroin ("smack," "H")	opiate	depresses neurons in brain stem; stimulates neurons in vomiting center; depresses neurons in cough-control center	breathing slowed; drowsiness; change of mood, mental clouding; perception of painful stimuli altered (reception of pain messages in the brain not affected); nausea and vomiting; pinpoint pupils; coma, death	Overdose causes death from breathing failure. It is addictive. Morphine, codeine, methadone, opium act in same ways.

Figure 10-3 (continued from page 48)

ADVANCED

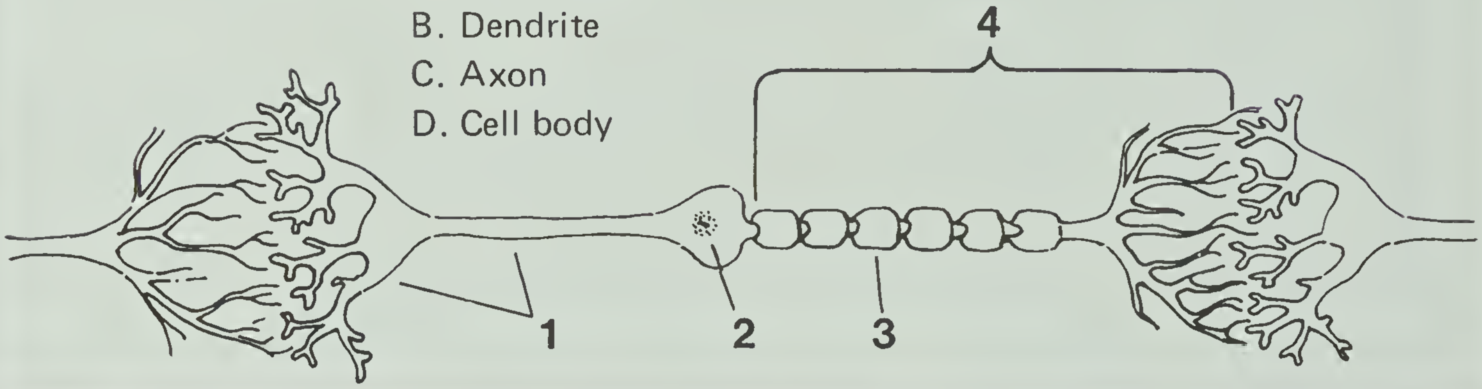
ACTIVITY 11: PLANNING

Activity 12 — Page 51

Objective 12-1: Identify four main features of a neuron (nerve cell), and tell what each does.

Sample Question: Match the four features of a neuron with the numbers on the diagram of the neuron below.

Feature	Neuron
A. Myelin cell	
B. Dendrite	
C. Axon	
D. Cell body	



Objective 12-2: Describe the changes in the membrane surface of a neuron as an impulse passes through it, and tell how the impulse is transferred to another neuron.

Sample Question: Which of the following best describes how an impulse is transferred from one neuron to another?

A. The end of one neuron becomes negatively charged, causing the release of a chemical that stimulates the next neuron.
B. Sodium ions, Na^+, are transferred from one neuron to the next.
C. Electrical sparks jump from the end of one neuron to the next.
D. The entire neuron receives a charge, which is then passed on to the next neuron.

Activity 13 — Page 56

Objective 13-1: Describe and compare the complexities of the nervous systems of the protozoans, hydra, grasshopper, frog, and human being.

Sample Question: Which of the following organisms have nervous systems that include ganglia?

A. Protozoan
B. Hydra
C. Grasshopper
D. Frog

Answers: 12-1. A3, B1, C4, D2; **12-2.** A; **13-1.** C, D

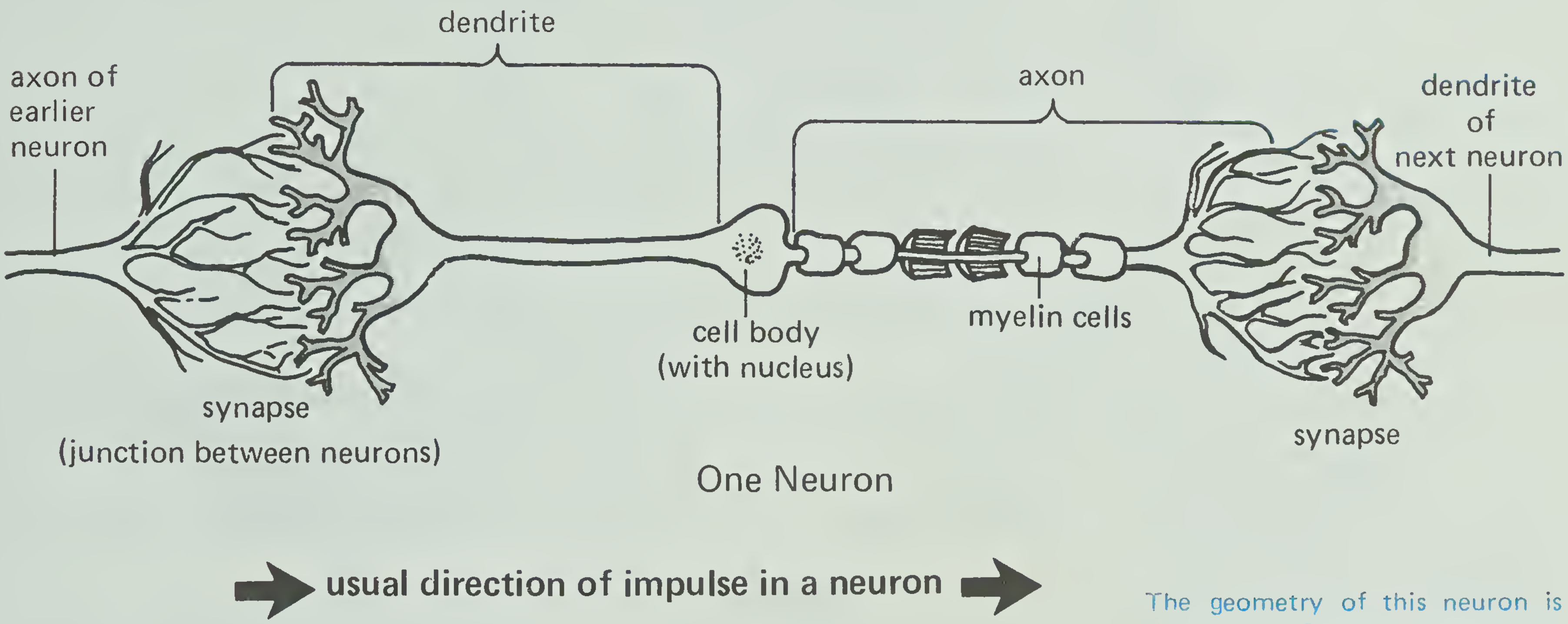
ACTIVITY 12: OBEYING IMPULSES

Nerve cells, or *neurons*, as they are called, make up the entire human nervous system. Your sensory nerves are made up of sensory neurons and your motor nerves of motor neurons. Your mixed nerves contain both types. A third type of nerve cell is called the *interneuron*. It is found in the brain and spinal cord. Ninety-nine percent of the body's ten billion or so neurons are interneurons.

Study Figure 12-1 below. It shows the usual pathway of a message, a nerve impulse, along a neuron. It also gives the main features of a typical neuron.

ACTIVITY EMPHASIS: Four main structural features of neurons are the dendrites, axon, cell body, and myelin sheath. A nerve impulse is a "moving" change of polarity of the nerve cell membranes. This change of polarity at the end of the axon causes the production of a chemical that stimulates the dendrites on the next neuron.

MATERIALS PER STUDENT LAB GROUP: See tables in "Materials and Equipment" in ATE front matter.



The geometry of this neuron is atypical. Generally, the axon is quite long compared to the dendrite.

Figure 12-1

☆ **12-1. What are the four main features of a neuron?**

12-1. Dendrite, cell body, myelin cells, and axon

● 12-2. The axon of one neuron is close to which part of the next neuron in the synapse?

12-2. The dendrite

The dendrites receive stimuli from other neurons through the synapses and send the information through the cell body. The cell body, which contains a nucleus, keeps the neuron alive and active. From the cell body, the impulse travels along the axon to the synapse with the next neuron.

12-3. The dendrite; the axon

● 12-3. Through which part does an impulse usually enter a neuron? Leave a neuron?

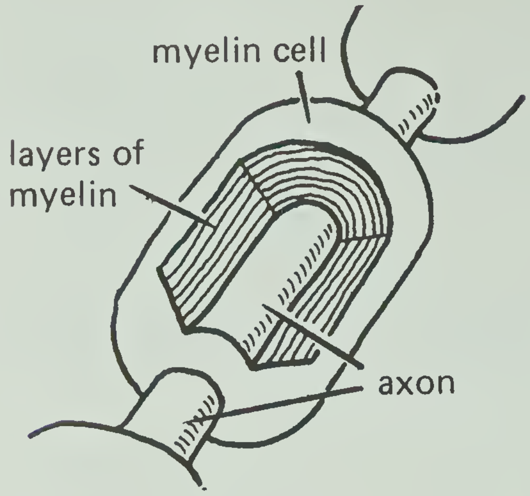


Figure 12-2

Myelin [MY-uh-lin] cells, found only with neurons, are wrapped around the axons, but not the dendrites. Myelin, the fatty substance found in these cells, seems to greatly increase the speed with which impulses move through a neuron. In general, the thicker the layer of myelin, the faster the impulses travel. A cross-section of a myelin cell is shown in Figure 12-2 at the left.

This discussion is highly simplified. It illustrates and describes a typical interneuron. Many neurons in the central and autonomic nervous systems may be unmyelinated.

● 12-4. Multiple sclerosis, a disease of the nervous system, destroys the myelin around certain neurons. What would you expect to happen to the speed of impulses in those neurons in the nervous system of a victim of multiple sclerosis?

12-4. The speed would decline.

12-5. A2, B1, C4, D3

☆ **12-5. Match the feature of the neuron with its function.**

Feature	**Function**
A. Cell body	**1. receives stimulus from another neuron**
B. Dendrite	**2. keeps the neuron alive and active**
C. Axon	**3. helps impulse to travel faster**
D. Myelin cell	**4. carries impulse to synapse with next neuron**

The ion exchange is far from complete. The K^+ concentration is always higher within the cell than outside it, and the Na^+ concentration is always higher outside the cell than within it. The passage of an impulse involves a change in the rates of diffusion. It also involves a reversal of polarity on the inner and outer surfaces of the neuron.

Stage 3 differs from Stage 1 mainly in the location of the Na^+ ions, which have temporarily dispersed within the cell. The "sodium pump" involves the use of energy to evacuate them, producing full recovery.

Scientists used to think that nerve impulses were like electric currents passing through wires. Nerve impulses do involve the flow of electricity, but the impulses travel more slowly than current in a wire does. Nerve impulse transmission is explained by the membrane theory described below.

Bundles of neurons are enclosed in insulating sheaths of special tissues in body organs and muscles. Salt solutions, similar to those in blood, bathe both the inside and outside of the membranes (cell surfaces) of the neurons.

In the solutions are ions, small particles that are either electrically positive or electrically negative. Holes in the neuron membrane allow certain types of ions to drift in and out of the cell. When an impulse passes, certain changes occur in these holes. Look at Figure 12-3 (page 53) and count ions. Then answer the questions below the figure. (You might also look at "Resource Unit 24: Atoms, Molecules, and Ions.")

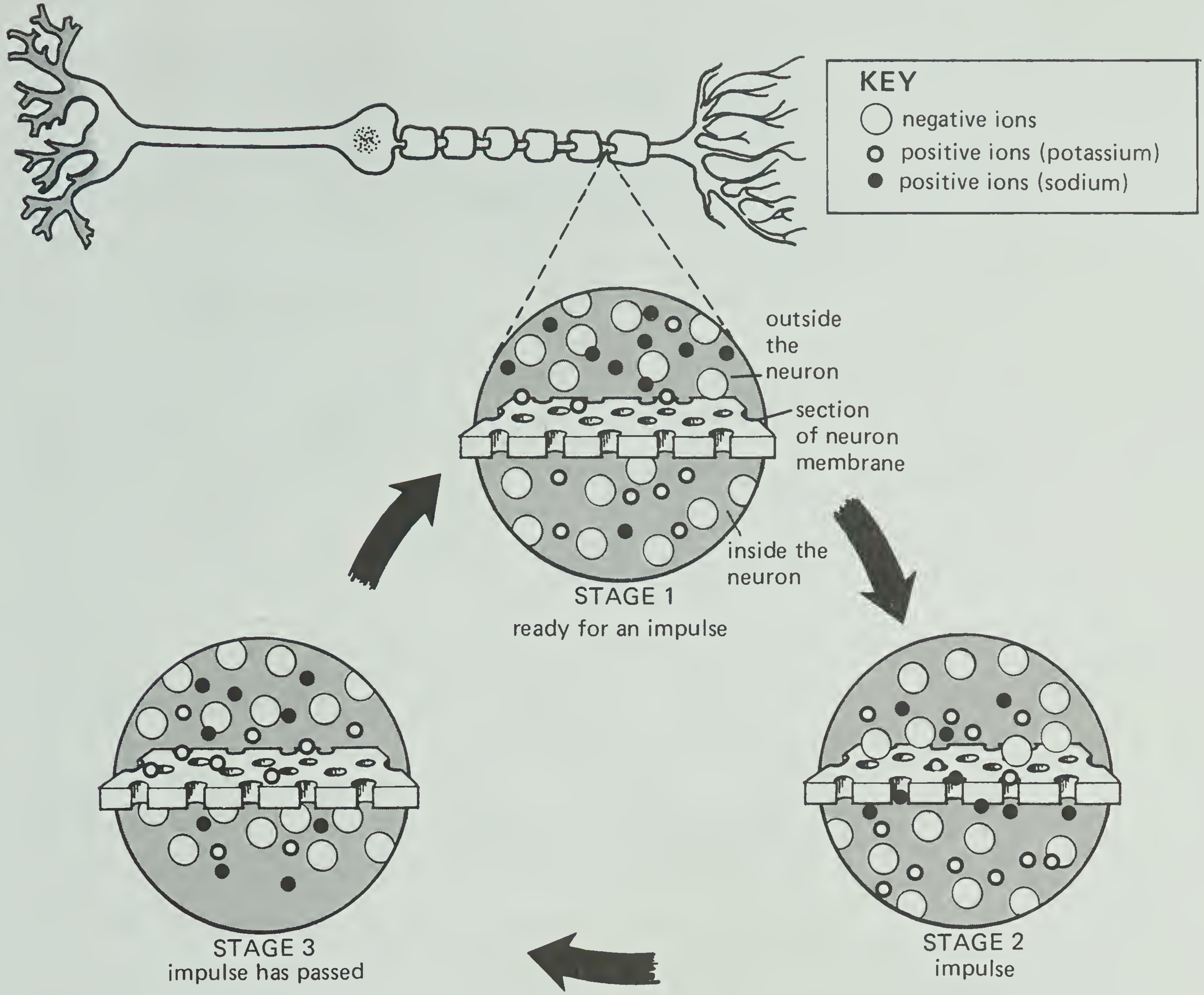


Figure 12-3

• 12-6. Which type of ion seems too large to pass through the holes in the neuron membrane?

12-6. Negative ions

• 12-7. Before an impulse arrives (Stage 1), which positive ions are found mostly inside the neuron? Mostly outside the neuron?

12-7. Potassium ions (6 inside); sodium ions (9 outside)

• 12-8. During an impulse (Stage 2), which positive ions enter the neuron?

12-8. Sodium ions (from 1 to 5 inside)

• 12-9. After an impulse has passed (Stage 3), which positive ions have left the neuron?

12-9. Potassium ions (from 7 to 2 inside)

• 12-10. What happens to the sodium and potassium ions between Stage 3 and Stage 1?

12-10. Sodium ions leave the cell, and potassium ions enter.

The ions present on each side of the neuron membrane determine the kind of charge held by that side.

The side of the neuron membrane with more positive than negative ions is positively charged. The side with more negative than positive ions is negatively charged. Look at Figure 12-4 below.

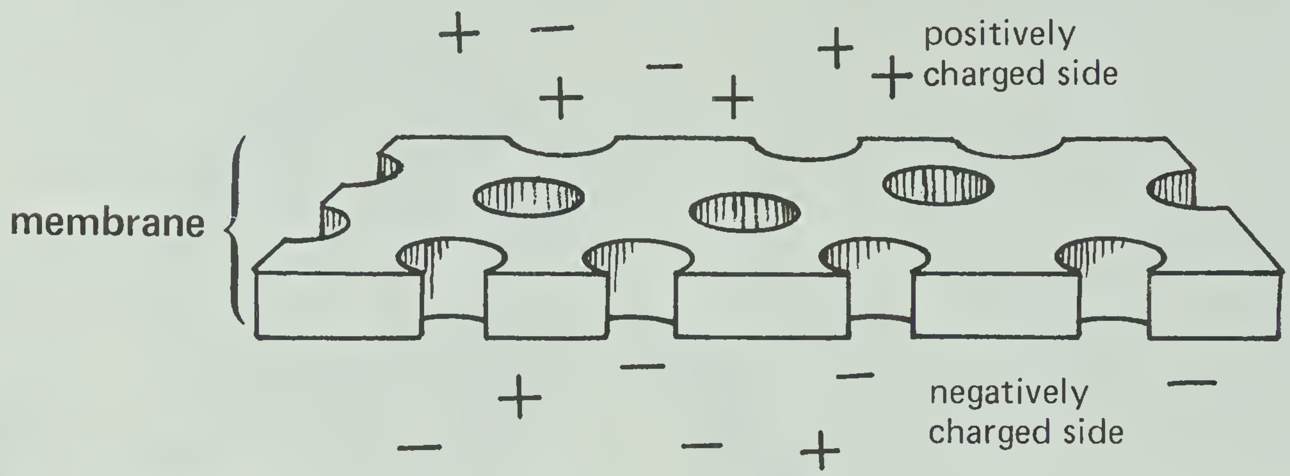


Figure 12-4

12-11. The outside; the inside; the outside

● 12-11. According to Figure 12-3 (page 53), which side of the neuron membrane is positively charged before an impulse arrives — the inside or the outside? How about during an impulse? Immediately after an impulse?

Figure 12-5 below and on page 55 shows how an impulse continues along the length of the neuron and on to the next neuron. Study it, and then answer Questions 12-12 through 12-14.

12-12. The membrane becomes positive (+) on the inside and negative (—) on the outside.

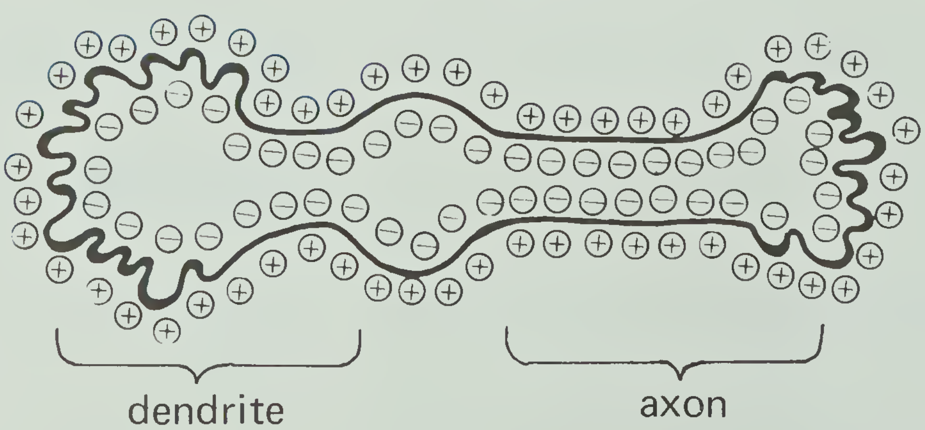
12-13. It goes back to its original state, positive (+) on the outside and negative (—) on the inside.

12-14. The change in the electrical charge causes a chemical to be produced, which stimulates the next neuron to carry the impulse.

☆ **12-12. What happens to the neuron membrane when it is stimulated and the impulse passes by?**

☆ **12-13. What happens to the neuron membrane after the impulse passes?**

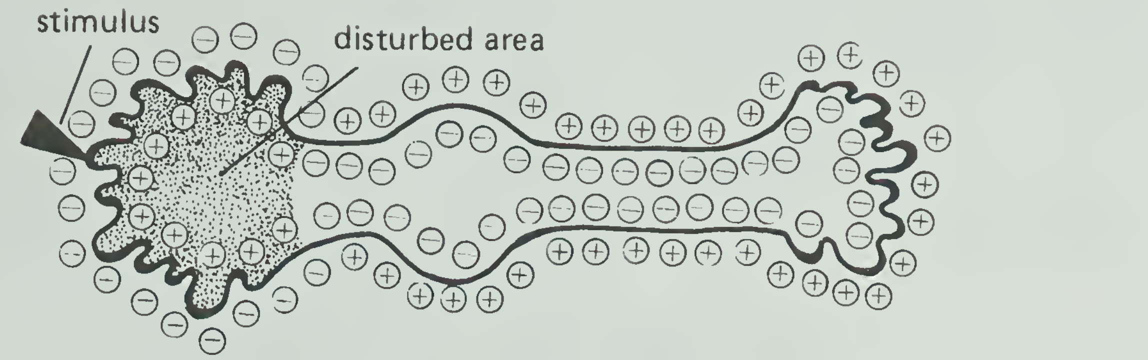
☆ **12-14. Describe how nerve impulses are sent from one neuron to another.**



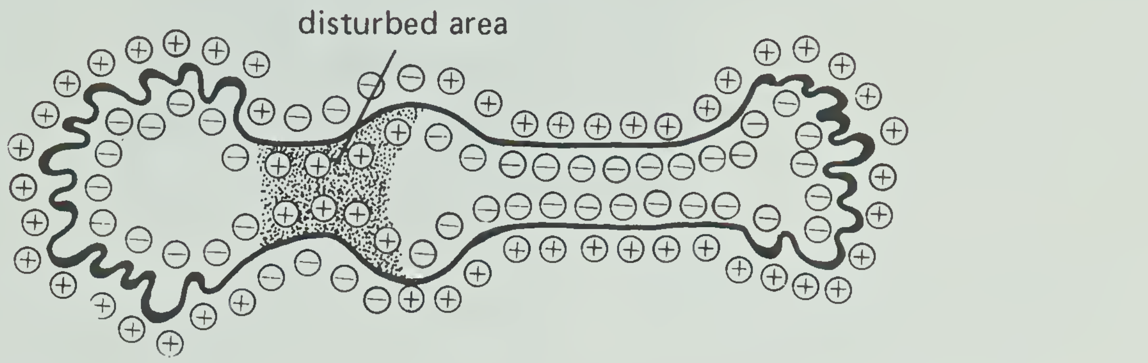
1. Before stimulation, a neuron is positively charged on the outside and negatively charged on the inside.

Figure 12-5 (continued on page 55)

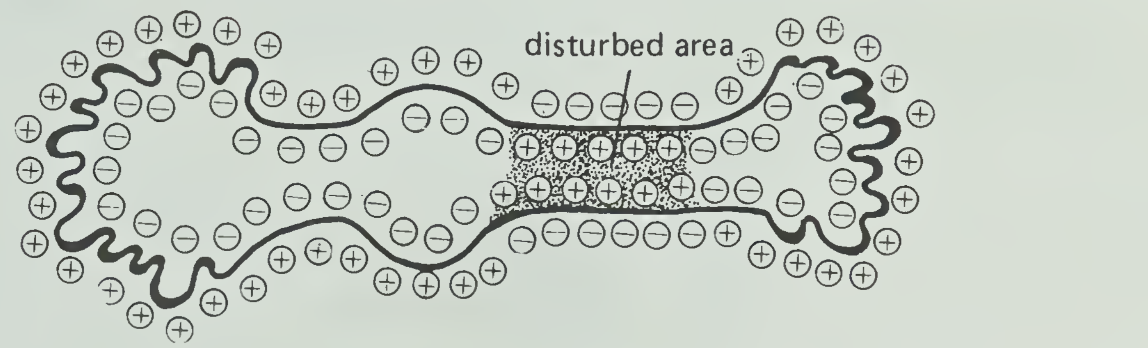
2. When the dendrites are stimulated and an impulse is produced, there is a change in the holes in the membrane. Positive (+) sodium ions are free to enter the neuron and the membrane reverses its charge. It becomes positively charged on the inside and negatively charged on the outside.



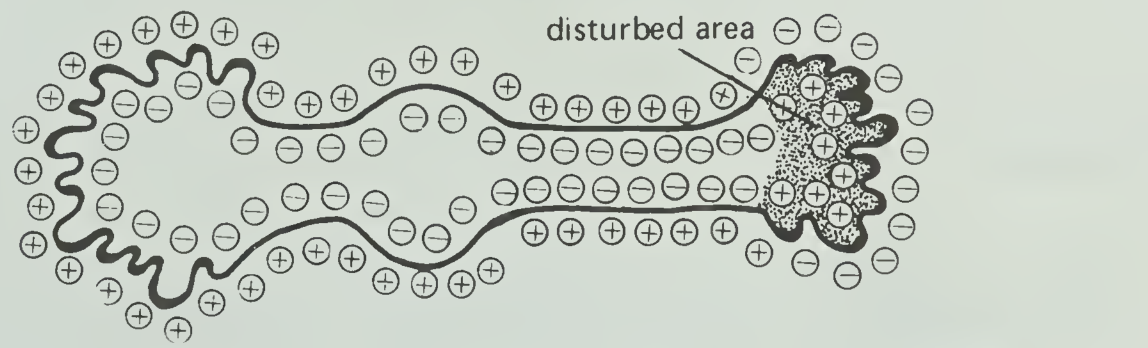
3. Wherever the nerve impulse is passing, the outside of the membrane is negative (–) and the inside is positive (+). This disturbance acts as a stimulus to the region just ahead of the impulse, causing it to become disturbed too.



4. Behind the impulse, in its wake, positive (+) potassium ions leave the neuron. Thus the outside of the membrane becomes positively charged again. The region is again in its resting state, ready for the next stimulus.



5. So the nerve impulse can be described as a "traveling disturbance" in the neuron, passing through the cell like a ripple until it reaches the end of the axon.



6. At the axon end, the impulse causes the production of special chemicals. These are released into the synapse and stimulate the dendrites of the next neuron. Then the impulse moves along in the same way as in the first neuron.

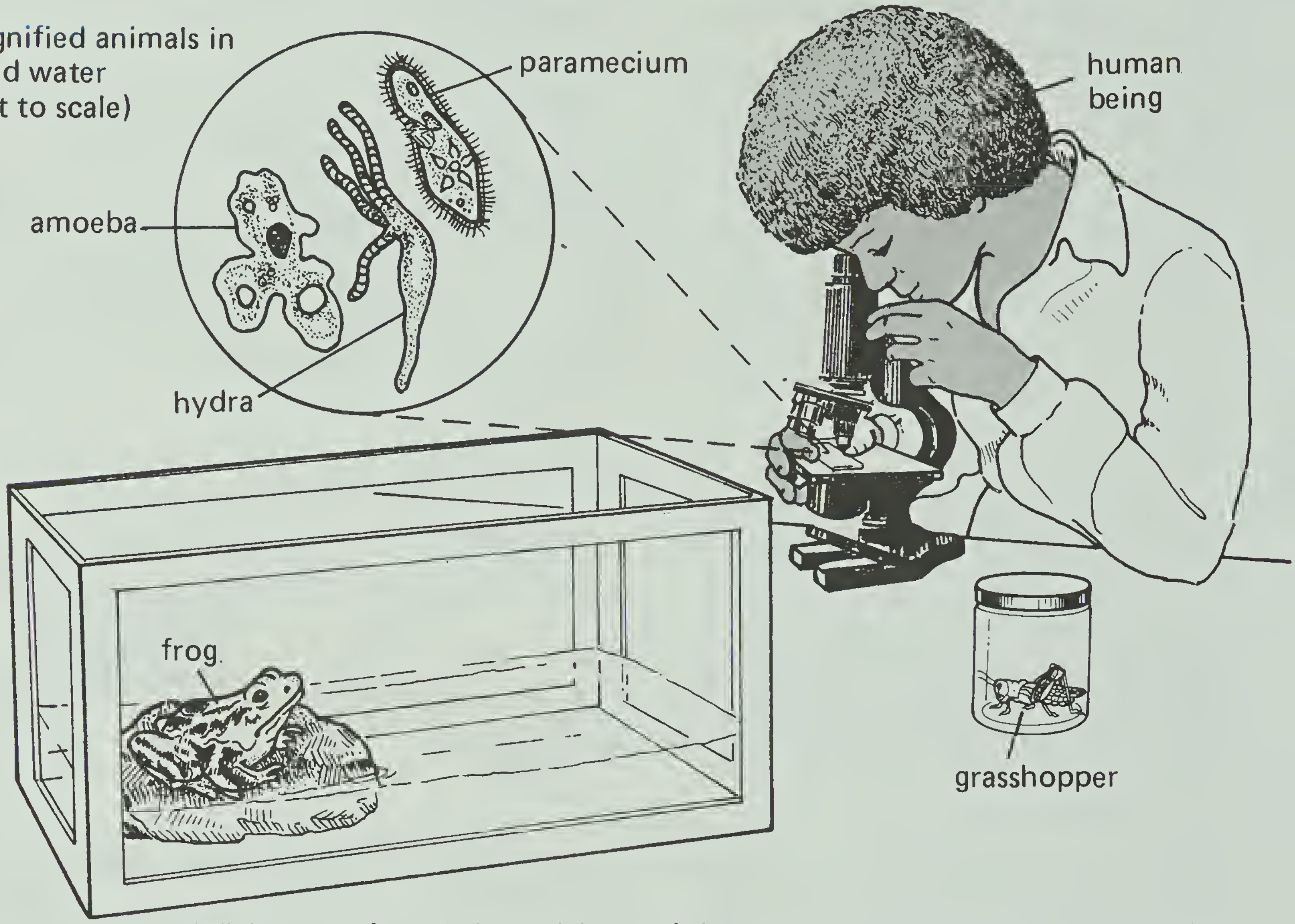
Figure 12-5 (continued from page 54)

ACTIVITY EMPHASIS: The degree of complexity and specialization in an organism's nervous system affects the organism's ability to respond selectively to stimuli.

MATERIALS PER STUDENT LAB GROUP: None

ACTIVITY 13: KINDS OF NERVOUS SYSTEMS

All animals — from the simplest to the most complex — respond to environmental stimuli. Some organisms lack nerve cells completely. Others have fairly well-organized nerve networks. Still others have highly complex, centralized nervous systems. The more complex and centralized an organism's nervous system is, the wider its range of responses to stimuli.



While you're doing this activity, you may also want to do parts of Activity 16. It will let you see many of the main parts of the nervous systems described in this activity. When you see an arrow next to a paragraph in this activity, do what the label says, if you're interested and the materials are available.

The amoeba is a good example of a simple, one-celled animal (protozoan) with no nervous system. Its only response to chemical and pressure stimuli is to flow toward or away from them. It will flow slowly toward food and slowly away from solid, nonfood objects.

Amoeba

13-1. By slowly flowing toward or away from stimuli

- 13-1. How does an amoeba respond to its environment?

Do Part 1 of Activity 16.

The paramecium is a more complex protozoan. It also responds to environmental stimuli by moving toward or away from them. But its movements are faster and better coordinated.

Thousands of hairlike structures on the paramecium's outer surface are connected beneath the surface by coordinating strands. These nervelike strands form a network throughout the animal's body so that all the hairs beat together in a wavelike motion. Figure 13-1 below shows the coordinating strands in the paramecium.

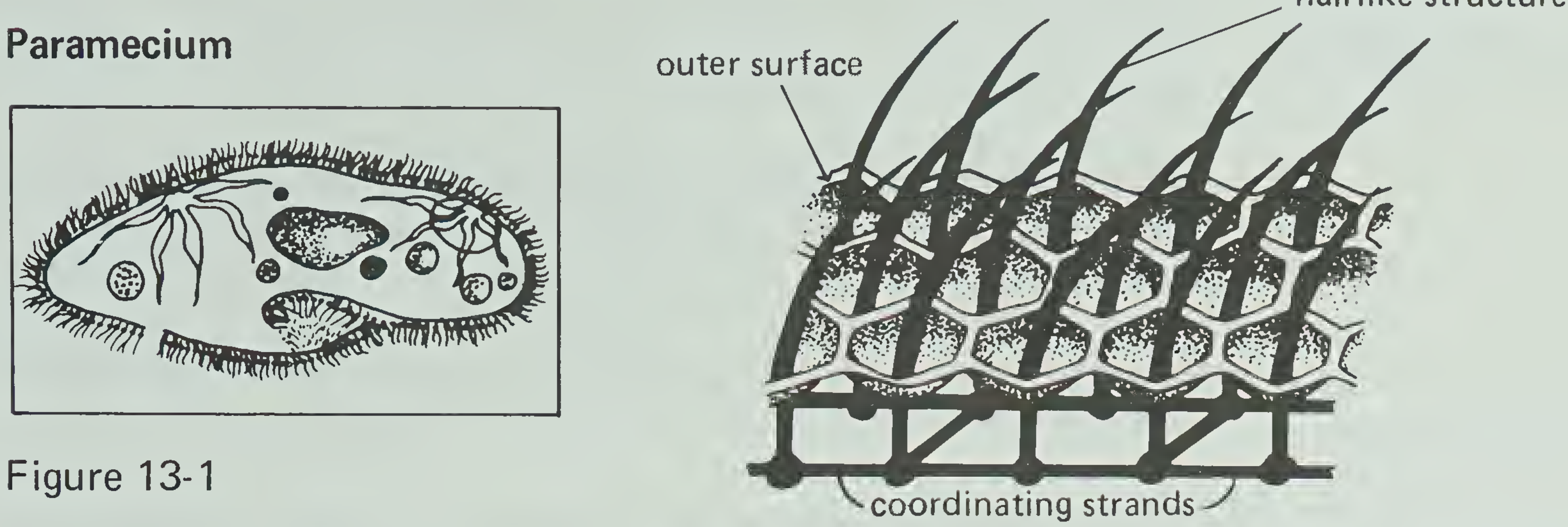


Figure 13-1

● 13-2. How does the network of coordinating strands coordinate a paramecium's movements?

13-2. The strands connect all the hairlike structures together so their movements may be coordinated.

☆ **13-3. How is the paramecium's network of coordinating strands superior to the way the amoeba reacts to environmental stimuli?**

13-3. The network of coordinating strands allows for faster, more coordinated reactions to environmental stimuli.

Do Part 2 of Activity 16.

A somewhat more complex network is found in the hydra. The hydra's body consists of many different kinds of cells. Specialized sensory cells on the hydra's outer surface receive stimuli from the environment. The sensory cells are connected to one another and to other kinds of cells by a nerve net, a network of nerve cells. Nerve impulses go from sensory cells through the nerve net to other kinds of cells, such as muscle, sting, and digestive cells, which then react. This simple nervous system controls and coordinates activities such as those shown in Figure 13-2 below.

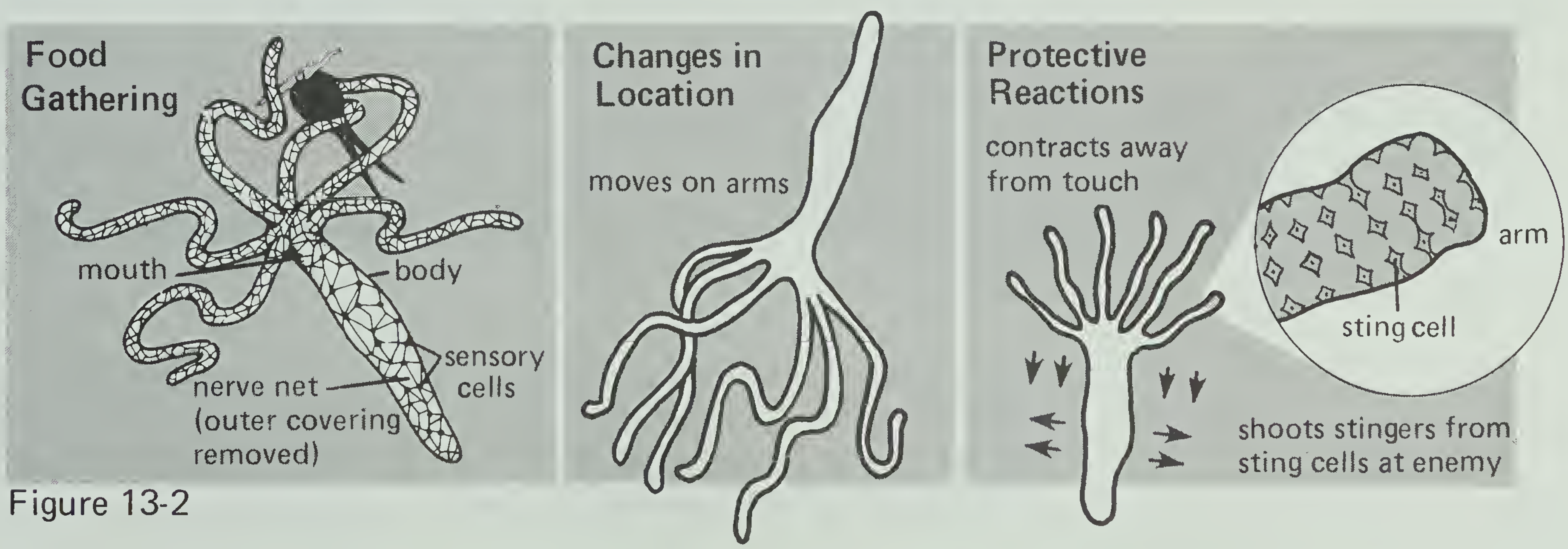


Figure 13-2

13-4. The hydra has specialized sensory cells.

13-5. They receive specific environmental stimuli.

13-6. Feeding, changes in location, and protective reactions

13-7. They are more complex, consisting of a brain or brainlike structure, a central nerve cord, and peripheral nerves.

☆ **13-4. What makes the hydra's nervous system superior to the network of coordinating strands used by the paramecium?**

● 13-5. In the hydra, exactly what function do the sensory cells perform?

● 13-6. A hydra has nerve fibers leading to muscle cells. What responses does this arrangement make possible?

Insects, frogs, and human beings have even more complex nervous systems. Each of these organisms has a brain or a brainlike structure that controls many body activities, a central nerve cord that connects the different areas of the nervous system, and many peripheral nerves that carry messages to and from the body parts. These are the main structures of a nervous system.

☆ **13-7. How are the nervous systems of insects, frogs, and human beings similar to each other and different from those of protozoans and hydra?**

Do Part 3 of Activity 16.

Figure 13-3 below shows the nervous system of a grasshopper.

Grasshopper

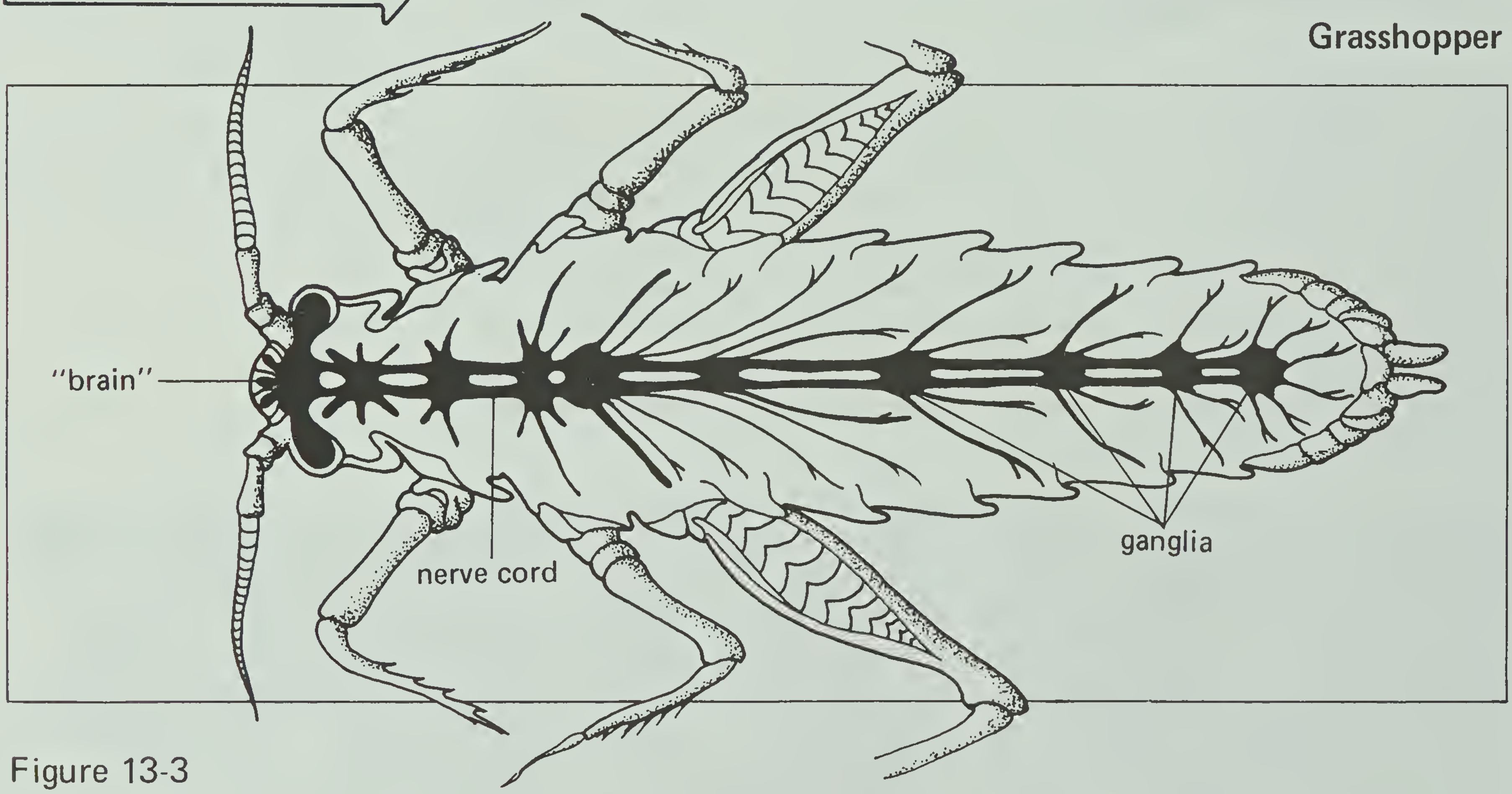


Figure 13-3

The grasshopper's nerve cord is made up of a series of connected ganglia. Each ganglion is a cluster of nerve cells that coordinates certain local body activities. From the ganglia, nerves reach muscles, glands, and sense organs.

In insects and some other lower animals, the "brain" is the forward-most group of ganglia. This "brain" has direct connections with the mouth parts, eyes, and antennae. It coordinates their actions.

• 13-8. What is a ganglion? Tell what a ganglion does in a grasshopper's body.

13-8. A ganglion is a cluster of nerve cells. It coordinates certain local body activities.

Although somewhat centralized, the grasshopper's nervous system is still primitive. The leg, wing, eye, and mouth muscles are each controlled by only a small number of neurons (as few as two or three).

• 13-9. Why can a grasshopper's leg perform only a few different kinds of actions?

13-9. There are only a few neurons leading to the leg muscles.

The frog's nervous system has much in common with the human nervous system. But there are also many differences. Figure 13-4 below shows the brain and upper nerve cord of the frog. Figure 13-5 below shows these structures for the human being. Compare them.

Do Parts 4 and 5 of Activity 16.

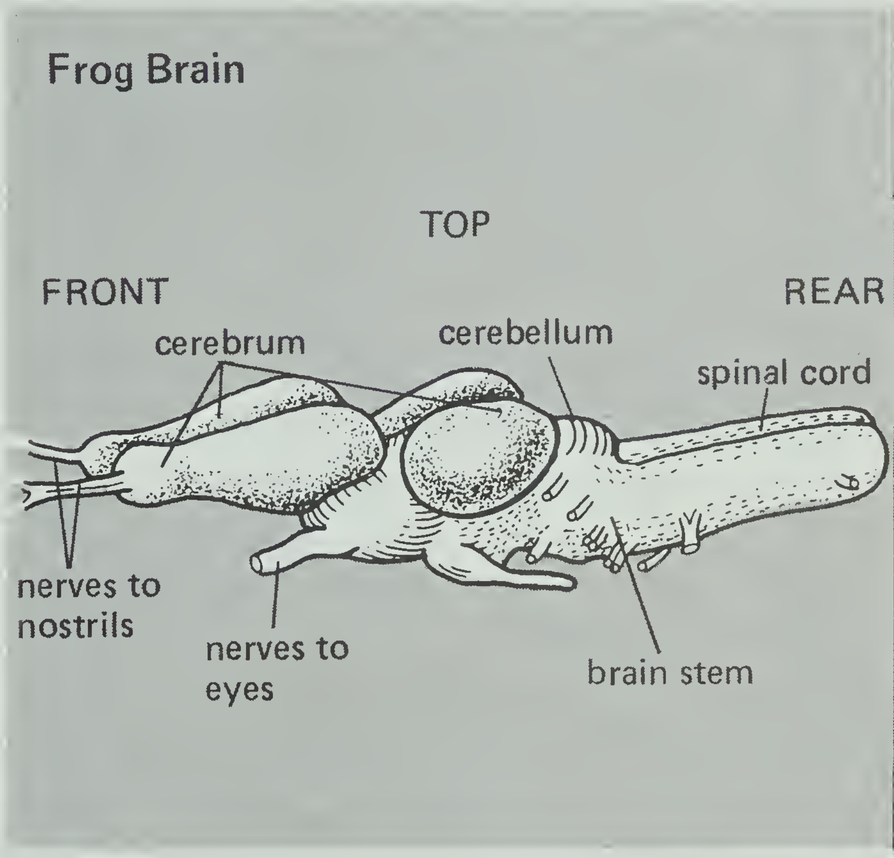


Figure 13-4

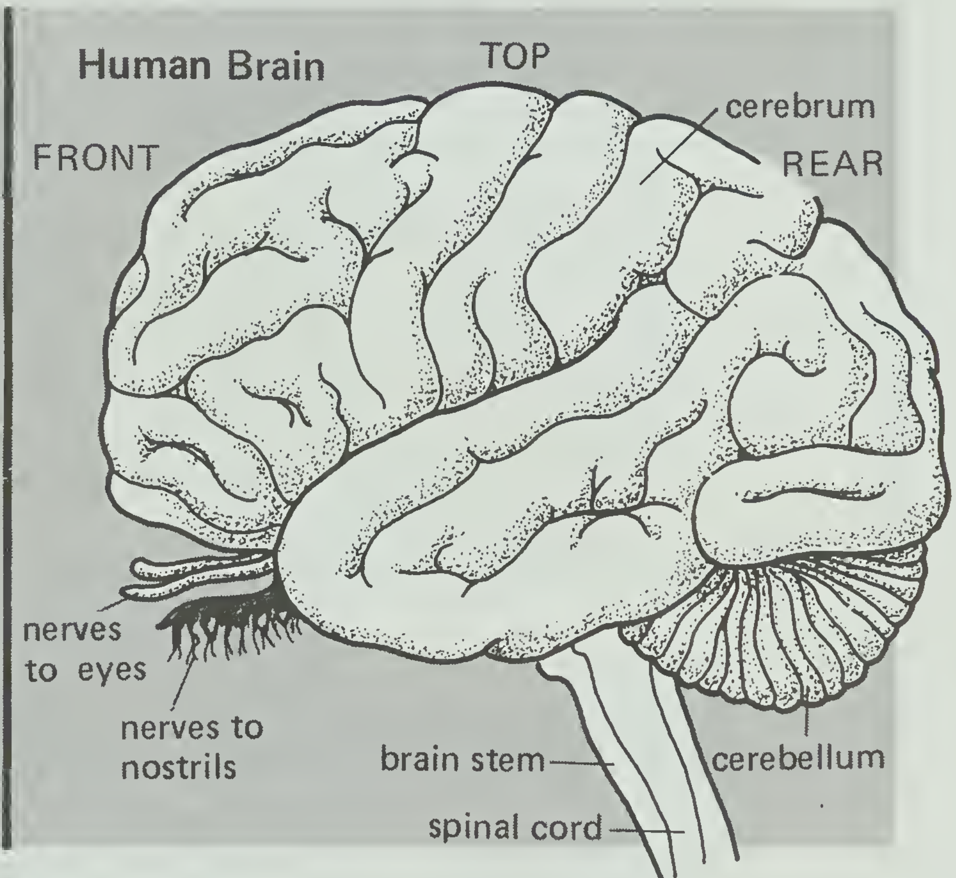


Figure 13-5

Higher animals, such as frogs or human beings, have a very complex brain and central nerve cord made up of many interconnected ganglia. The brain of lower animals functions like the brain of higher forms, but it is far less complex in structure.

13-10. The human brain has much more cerebrum.

• 13-10. Other than size, what is the most obvious difference between the frog brain and the human brain?

About ninety percent of the weight of the human brain is that big, wrinkled structure that fills most of the skull — the cerebrum. A frog's cerebrum is small and unwrinkled.

In both organisms, nerve centers in the brain control and coordinate many of the activities of the body, both conscious and unconscious. The complexity of an organism's responses is related to the number of these nerve centers and how interconnected they are. Accordingly, human beings can talk, exercise judgment, and make elaborate plans. Frogs can't.

13-11. It is less complex. The human brain can think or plan conscious acts. The grasshopper is limited mainly to reflex actions.

☆ **13-11. How does a grasshopper's nervous system compare in complexity with that of a human being? How is this reflected in behavior?**

13-12. It is less complex, especially because its cerebrum is much smaller. The frog can do fewer conscious acts, such as thinking and planning.

☆ **13-12. How does a frog's nervous system compare in complexity with that of a human being? How is this reflected in behavior?**

13-13. F, D, B, A, C, E

☆ 13-13. Arrange the following nervous systems in order of complexity. List the least complex first and the most complex last.

A. Central nervous system of grasshopper
B. Nerve net of hydra
C. Central nervous system of frog
D. Network of coordinating strands of paramecium
E. Central nervous system of human being
F. Response activities of amoeba (lacks nervous system)

13-14. A4, B5, C2, D1, E3

☆ 13-14. Match each of the organisms listed below with the proper description of its nervous system.

Organism

A. Protozoan
B. Human being
C. Frog
D. Grasshopper
E. Hydra

Nervous System Description

1. A partly centralized nervous system with a brain (or ganglia), a central nerve cord with ganglia, and nerves leading to body organs
2. A centralized nervous system with a small cerebrum, a large brain stem, a spinal cord, and nerves leading to body organs
3. A nerve network throughout the body wall and sensory cells on the body surface
4. Either no nervous system or a very primitive one with connecting strands that control swimming action
5. A highly centralized nervous system with a large cerebrum, a brain stem, a spinal cord, and many nerves leading to body organs

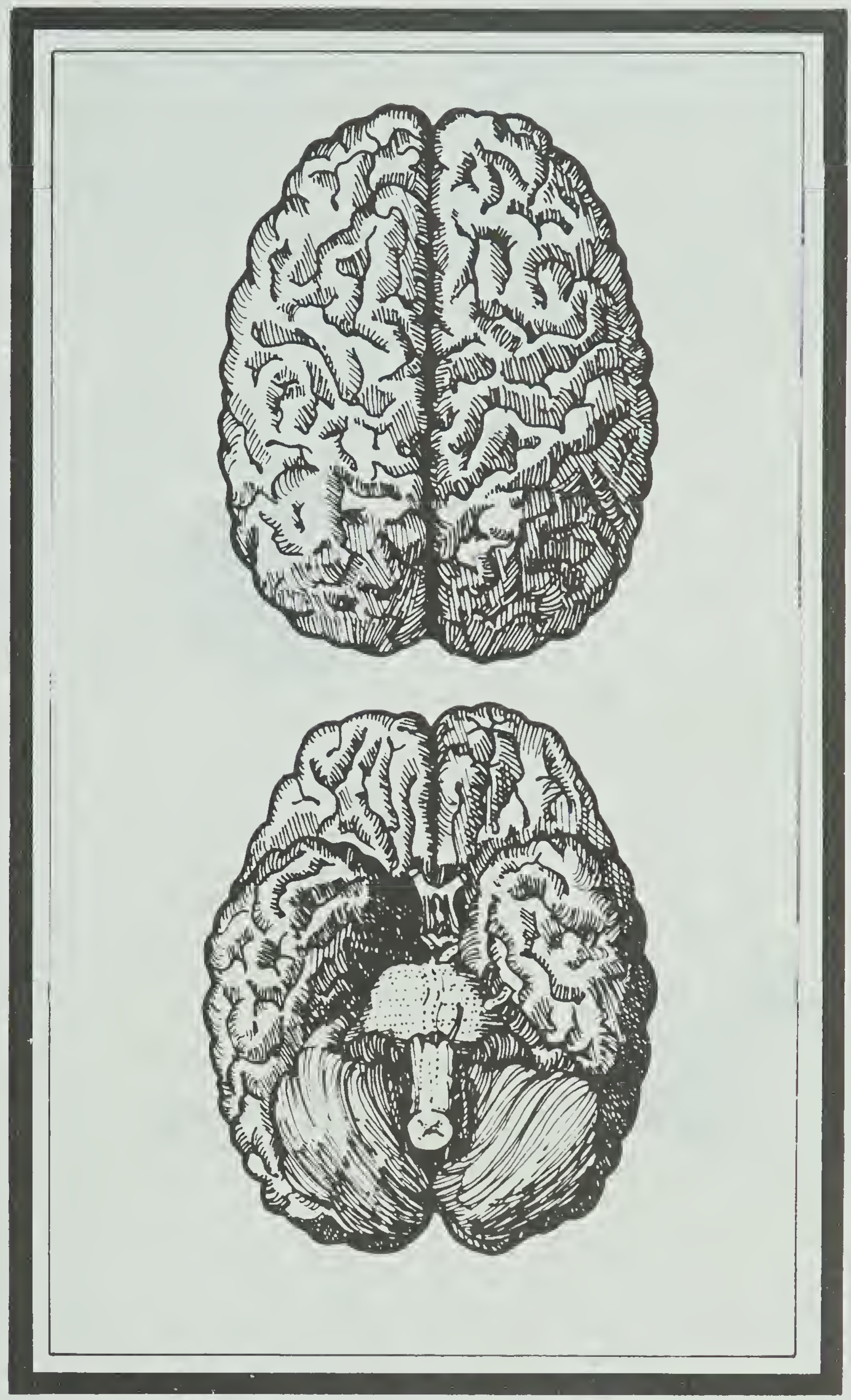
EXCURSION

ACTIVITY 14: PLANNING

Messages sent by radio, telegraph, and telephone all travel at the speed of light. Nerve messages, however, don't move that fast. In this activity, you'll learn what reaction time is, how to measure it, and how to improve it.

Different creatures have different kinds of nervous systems. Here's a chance to look at these systems and to compare them with your own. You'll examine protozoans, hydra, a grasshopper, a frog, and a model of the human body.

Many sensations, muscle movements, and even speech functions are centered in particular areas of the brain. In this activity, you'll learn where these areas are and how scientists were able to discover and map them.



ACTIVITY EMPHASIS: Reaction time is the time between a stimulus and the beginning of a resulting response. It is the time required for an impulse to travel from the sense organ to the central nervous system and another impulse to travel back to an effector organ.

MATERIALS PER STUDENT LAB GROUP: See tables in "Materials and Equipment" in ATE front matter. See "Advance Preparations" in ATE front matter.

ACTIVITY 15: QUICK THINKING

Perhaps there are times when you know in your brain what you want to do, but your body takes a little longer to do it. Test how fast your body reacts in the following investigation. All you'll need is a partner and a reaction-time ruler.

	REACTION TIME	
	Self (in s)	Partner (in s)
Trial 1		
Trial 2		
Trial 3		
Trial 4		
Trial 5		

A. First, copy this table into your notebook.

B. Hold the reaction-time ruler at the top so that it hangs between your partner's open thumb and fingers. The thumb mark on the ruler should be level with your partner's thumb.

C. When your partner is ready, let the ruler drop. Your partner should catch it quickly between thumb and fingers. Then read the number of seconds just above your partner's thumb and enter it in the table for Trial 1.

D. Drop the ruler four more times. Record the time for each trial. Then switch places with your partner. Let your partner check your reaction time through five trials and record the results.

Reaction time is the time your body takes to respond after it receives some kind of stimulus. In this case, the stimulus was the sight of the ruler starting to fall. The response was the closing of thumb and fingers on the ruler.

The reaction-time ruler is calibrated in fractions of a second, based on a formula relating time, distance, and gravitational force: $d=\frac{1}{2}gt^2$.

● 15-1. What was your shortest reaction time in the investigation?

15-1. [Answers will vary, but 0.20 s is about average.]

● 15-2. How did your reaction time in the first trial compare with your reaction time in the last trial?

15-2. [Answers will vary, but there was probably some improvement after several trials.]

● 15-3. Were you or your partner ever able to catch the ruler before any time at all had passed?

15-3. No

You read in the core that for voluntary actions, a stimulus causes a nerve message to be sent to the brain. The brain then sends a message to the body muscles, and the body reacts.

Your reaction time was the total time between stimulus and response. Almost all of that time was used up by nerve messages traveling from a sense organ — your eye — to your brain and then from your brain to your finger muscles. Look at Figure 15-1 below.

The length of the neuron from brain to finger can be estimated by using reaction time and the speed of a typical nerve impulse (100 m/s).

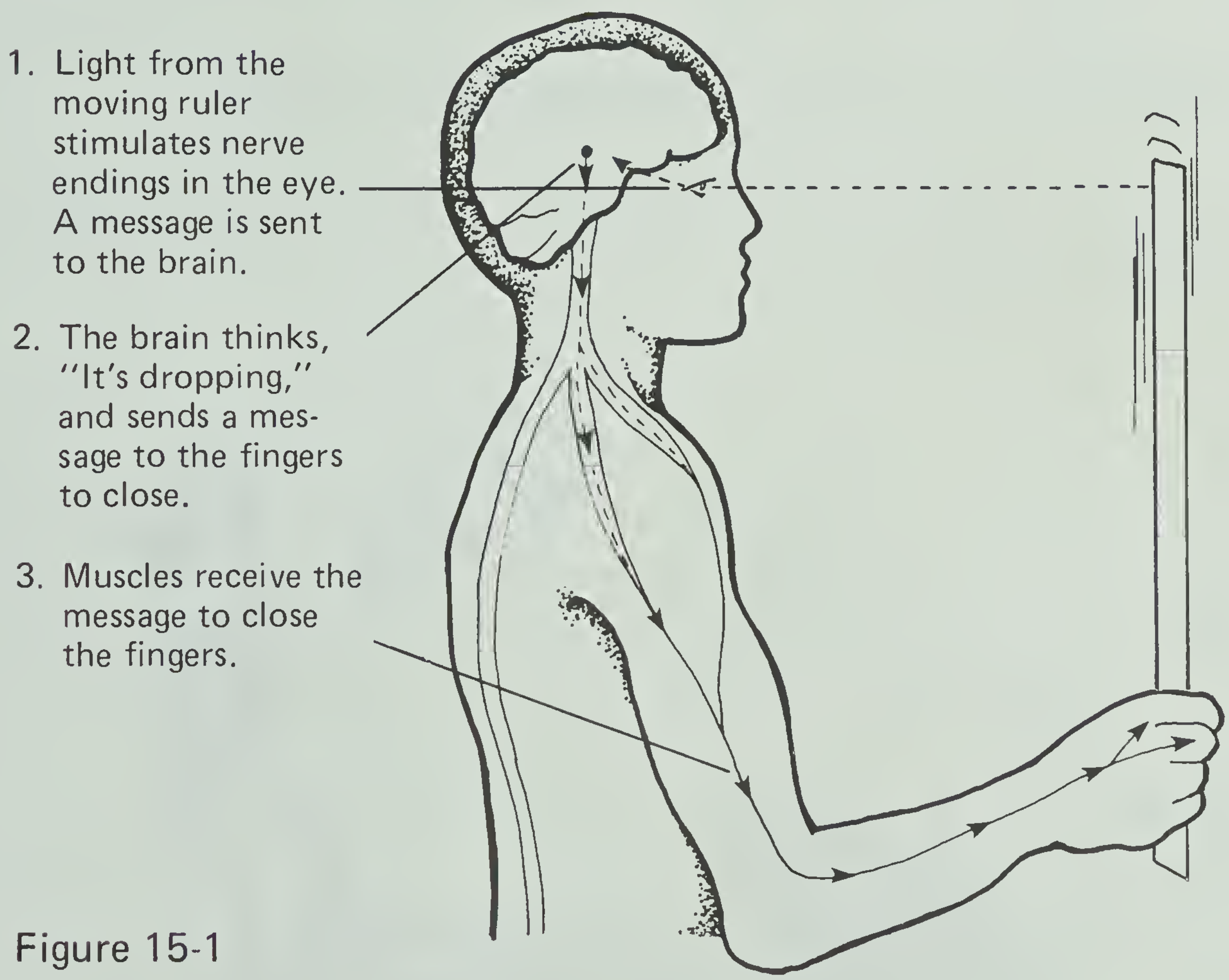


Figure 15-1

☆ **15-4. Explain reaction time in terms of nerve messages.**

15-4. Reaction time is the time required to transmit nerve messages from the sense organs to the brain and from the brain to the muscles.

● 15-5. Why can reaction time never be zero?

15-5. Nerve transmission always takes some time.

"Jumping the gun" at the start of a race is a result of anticipation of a stimulus.

Athletes often have very quick reaction times. This is partly the result of practice. In your investigation, you probably improved your reaction speed as you practiced. Athletes also learn when to expect a stimulus. That helps them react quickly. It also might have helped you.

15-6. By practice and by learning when to expect a stimulus

☆ **15-6. Name two ways a person's reaction time can be shortened (improved).**

As you learned in the core, some psychoactive drugs stimulate (speed up) or depress (slow down) the brain. Stimulants make reaction time shorter, and depressants make it longer.

15-7. Their reaction times would be shortened.

● 15-7. What is one reason that athletes are not allowed to take stimulant drugs before competition?

15-8. It is increased (even though the person may think the opposite).

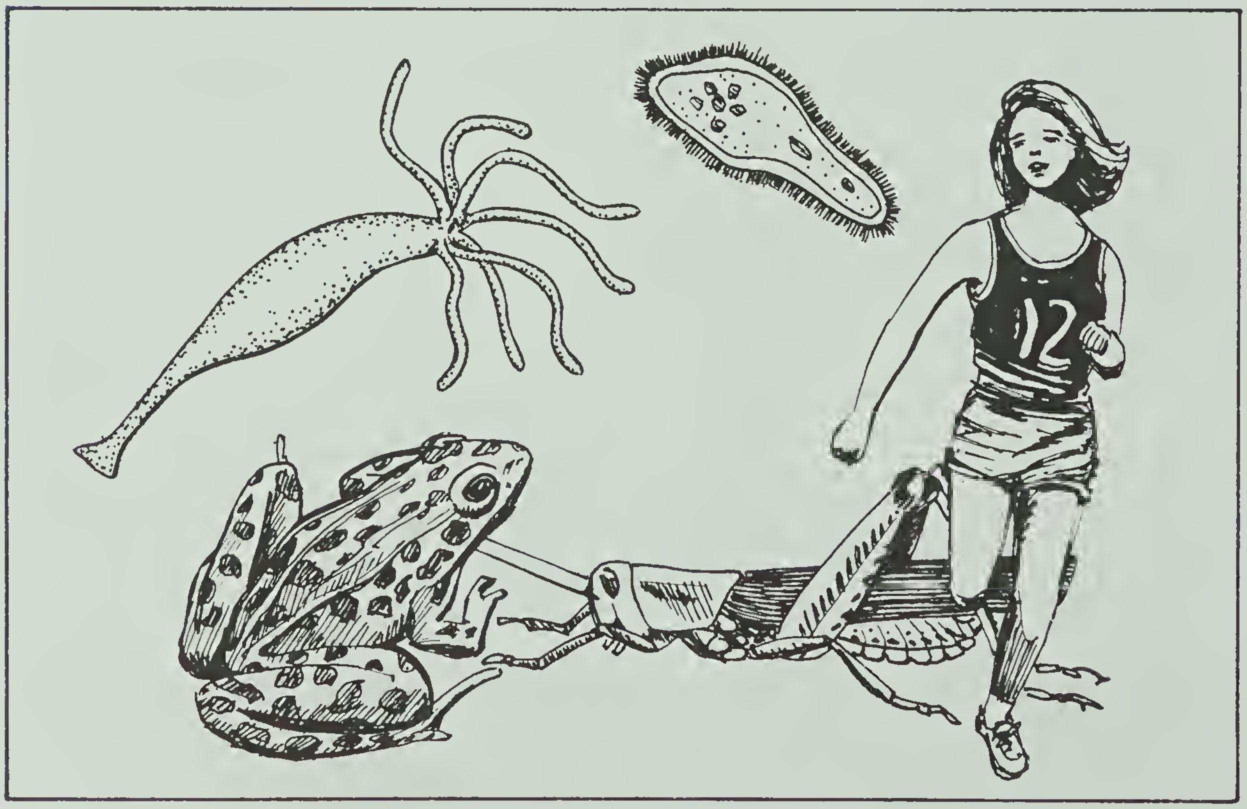
● 15-8. What happens to the normal reaction time of a drunk driver?

ACTIVITY EMPHASIS: The more centralized an organism's nervous system and the more specialized its nerve cells, the more specific and appropriate are the organism's reactions to environmental stimuli. This point can be shown both by observation of behavior and by examination of dissected specimens.

MATERIALS PER STUDENT LAB GROUP: See tables in "Materials and Equipment" in ATE front matter. See "Advance Preparations" in ATE front matter.

ACTIVITY 16: COMPARING NERVOUS SYSTEMS

In this activity, you'll look at the nervous systems of several organisms and compare them with each other. The investigation is divided into five parts.



Part 1: Protozoans

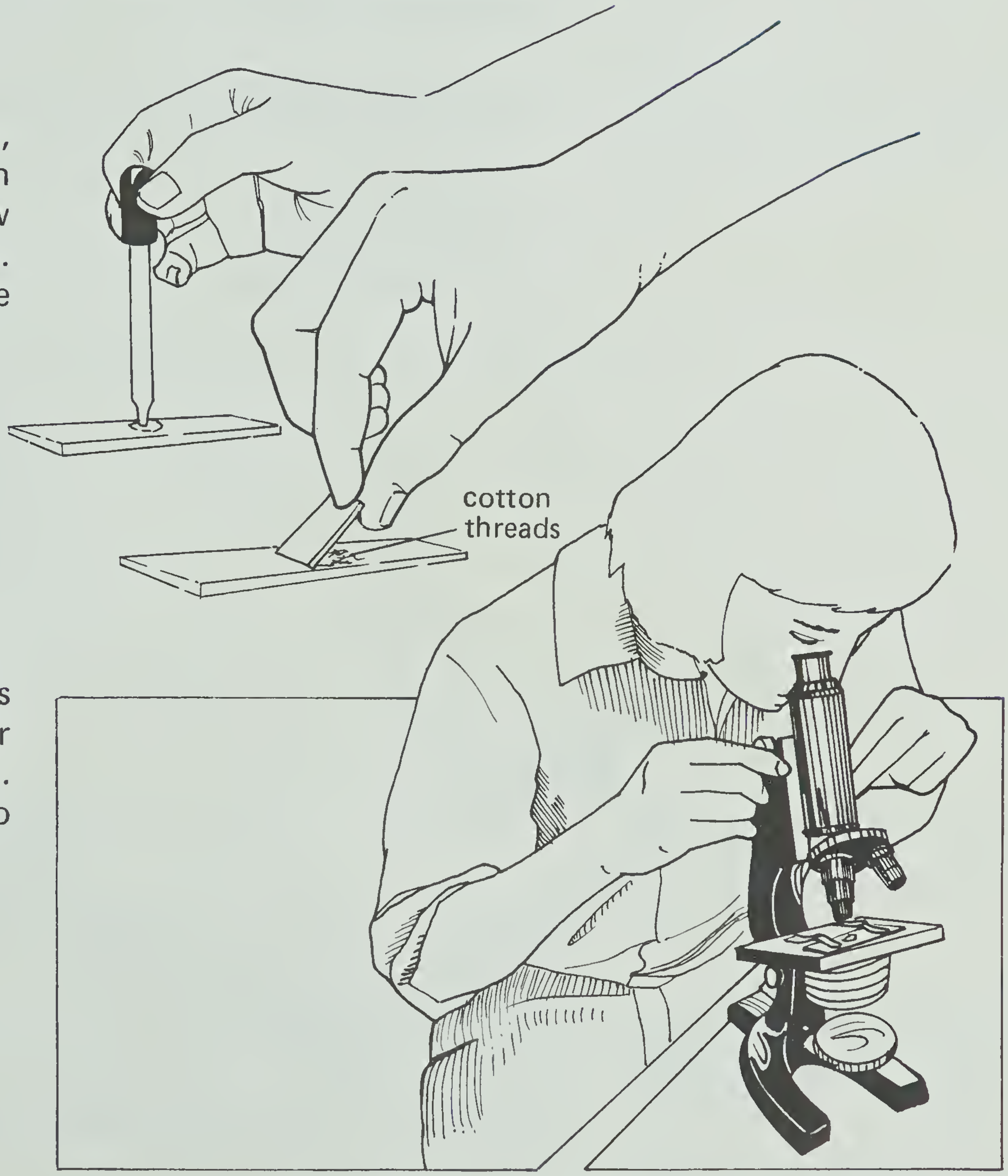
To look at the nervous responses of protozoans (one-celled animals), you will need the following materials.

Caution students to avoid getting pond-water culture on their hands or in their mouth or eyes.

pond-water culture
medicine dropper
microscope
glass slide
cotton threads
coverslip

If you're not sure how to use a microscope, check Part B of "Resource Unit 3: Using a Microscope." Then begin Step A.

A. With the medicine dropper, place a drop of pond water on the glass slide. Add a few cotton threads to the drop. Put the coverslip over the drop and threads.



B. First look at the protozoans (the fast-moving "dots") under low power of the microscope. Then switch to high power to observe them closely.

● 16-1. What do the protozoans do when they run into one of the cotton threads?

16-1. They change direction and swim away.

Protozoans are the simplest animals. They have no nervous system — no brain, no nerve cord, no sense organs. But some kinds of protozoans do have a nervelike network that helps them swim about. When stimulated, they respond by swimming away from "bad" environmental stimuli (such as cotton threads) and toward "good" stimuli (such as food).

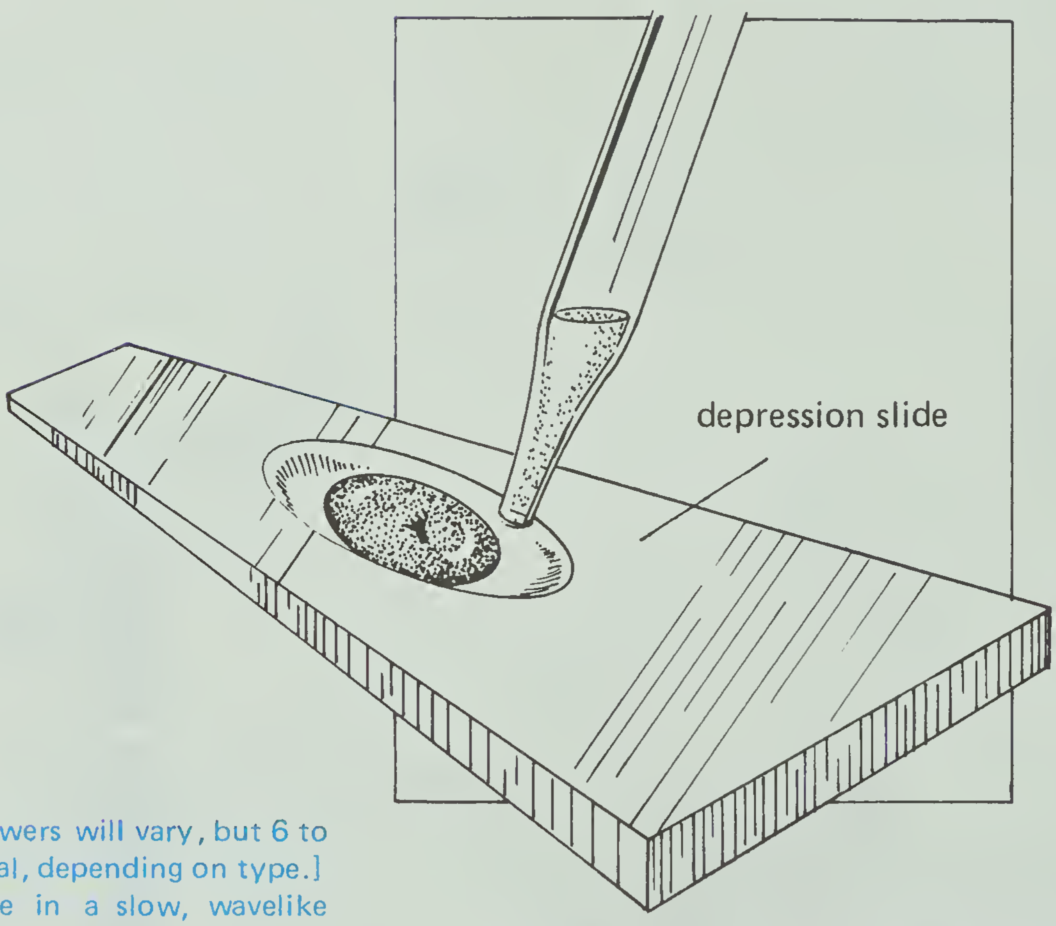
16-2. They swim either toward or away from them.

● 16-2. Describe how protozoans respond to most environmental stimuli.

Part 2: The Hydra

To see the hydra's nervous system in action, you'll need the following materials.

live-hydra culture
medicine dropper
microscope
depression slide
dissecting probe
tiny piece of meat



A. Using the medicine dropper, place a live hydra in the cavity of the depression slide. Add just enough water to fill the cavity.

B. View the hydra under low power. Watch its movements. Tap the slide lightly, and notice what happens.

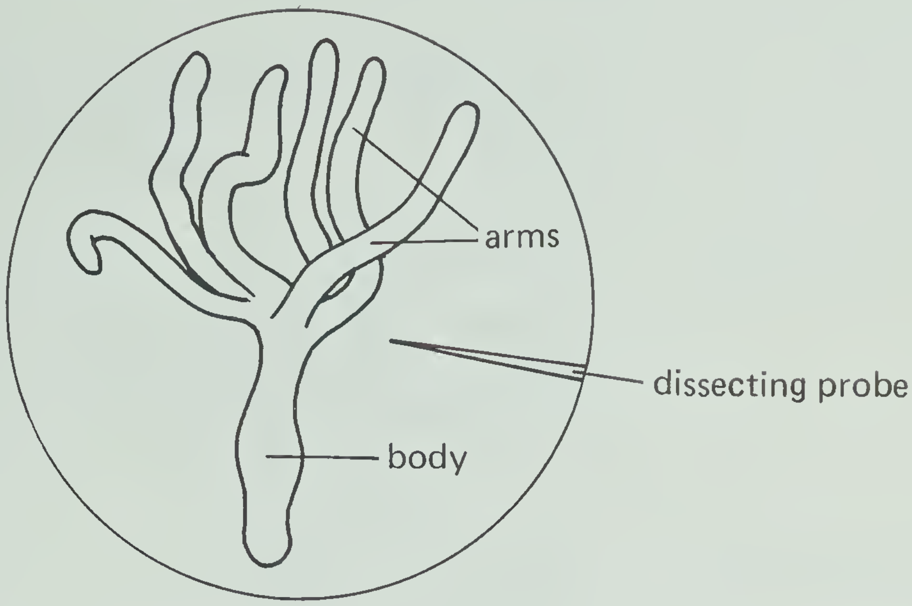
16-3. [Answers will vary, but 6 to 10 is normal, depending on type.] They move in a slow, wavelike manner.

16-4. [Answers will vary. Often the hydra shortens its body by contracting.]

● 16-3. How many arms does the hydra have? Do they move? In what manner?

● 16-4. How did the hydra respond when you tapped the slide?

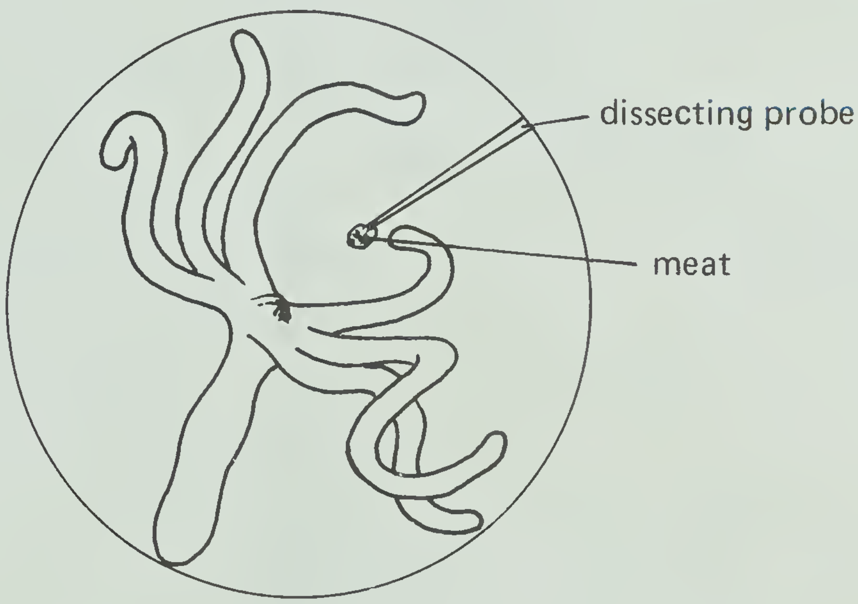
C. Using a clean dissecting probe, gently touch the hydra's body and arms. Do this several times, allowing five seconds between contacts.



● 16-5. How did the hydra's body respond to the probe's touch? How did the arms respond when touched?

16-5. The body contracts (shortens) when touched. The arms move away and contract slightly, with the body also contracting.

D. Stick a tiny speck of meat on the end of the probe. Then carefully bring it into contact with one of the hydra's arms. Watch what happens.



● 16-6. How did the hydra respond to the food?

16-6. [Answers will vary; the hydra may move toward the food, surround it, and possibly try to eat it.]

Hydras, which live in cool, fresh water, have no brain and thus very poor central control. Their nervous system is simple – interconnecting fibers attached to sense cells on the body surface. When one part of a hydra's body is touched, the whole organism reacts by shrinking away from the stimulus. The sense cells can also tell when food is near, and usually the hydra moves toward it.

● 16-7. Describe how the hydra responds to environmental stimuli.

16-7. It moves toward or away from environmental stimuli.

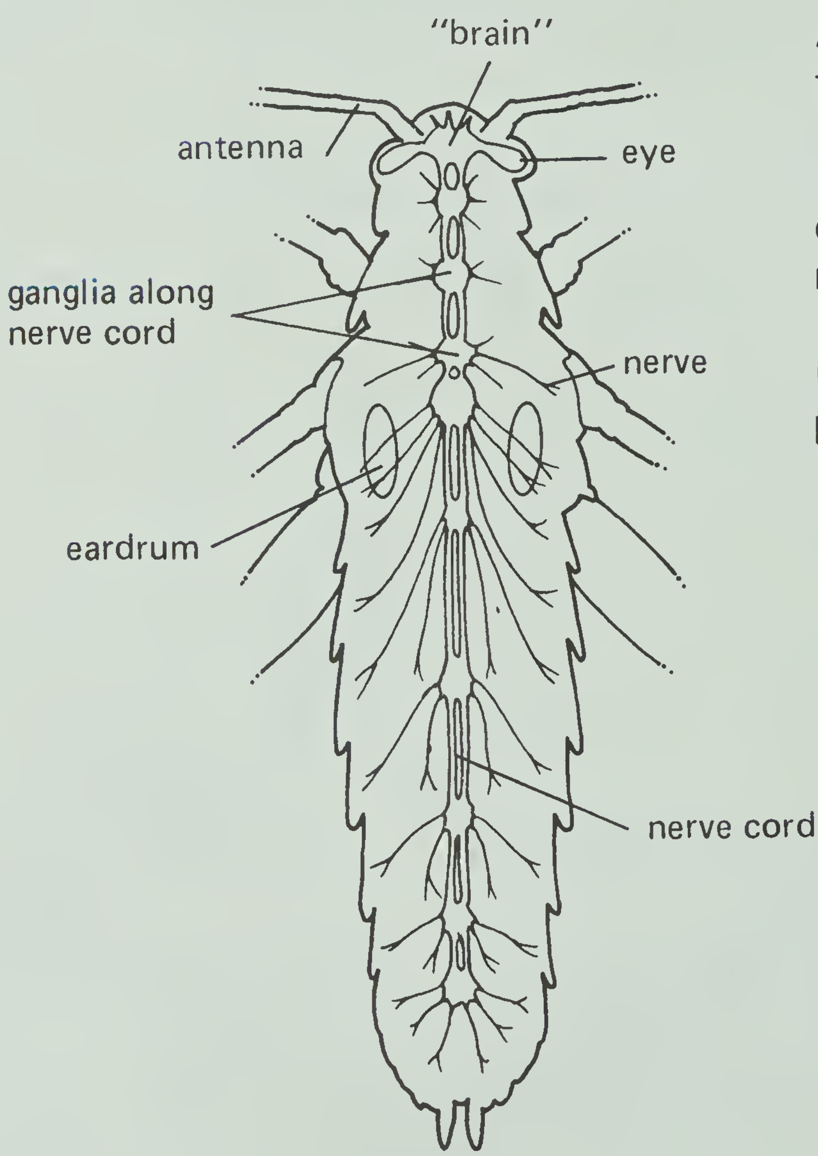
Part 3: The Grasshopper

The grasshopper has a true nervous system. It's a simple one, consisting of a brainlike structure and a nerve cord (the basics of a central nervous system) and a set of nerves. Some of the grasshopper's nerve cells are also in clusters called *ganglia* [GANG-glee-ah] and in a few sense organs. These include eyes, antennae, and eardrums. The grasshopper's nervous system is partly in its head and partly in the underside of its body.

To examine a grasshopper's nervous system, you'll need the following materials.

See "Advance Preparations" in the ATE front matter for suggestions on dissection.

dissected grasshopper
dissecting pan
straight pins
dissecting probe



A. Pin the grasshopper down to the dissecting pan.

B. Use this diagram to help locate the "brain," nerve cord, nerves, and sense organs.

C. Answer Question 16-11 on page 70.

All the grasshopper's activities are reflexes — predictable responses to stimuli. The ganglia, including those of the "brain," coordinate local body movements. Because its "brain" is simple, the grasshopper can't think or plan like human beings can.

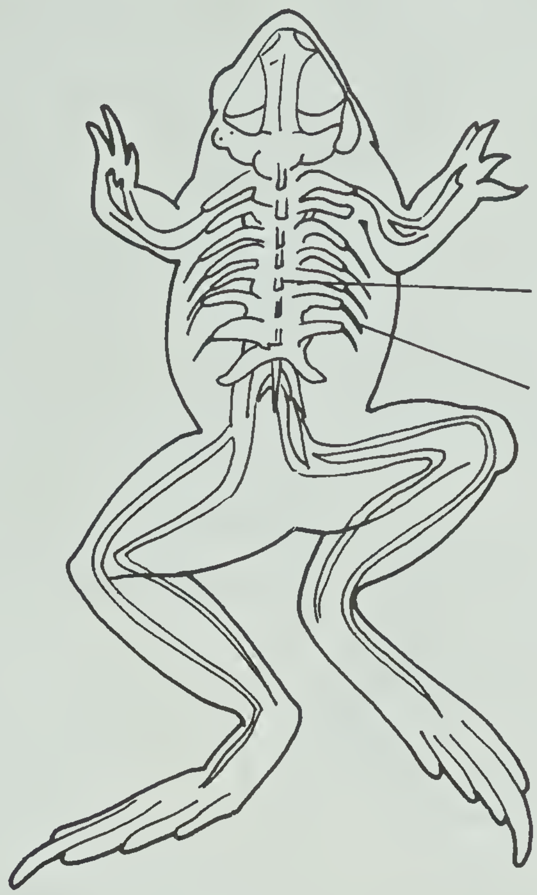
Part 4: The Frog

The frog has a nervous system with central control. The brain coordinates many body activities. To examine the frog's nervous system, you'll need the following materials.

dissected frog
dissecting pan
straight pins
dissecting probe

For step A the frog should be pinned ventral side up.

A. Pin the frog to the dissecting pan. Using the probe, locate the spinal cord and the nerves leading from it. Use this diagram for reference.

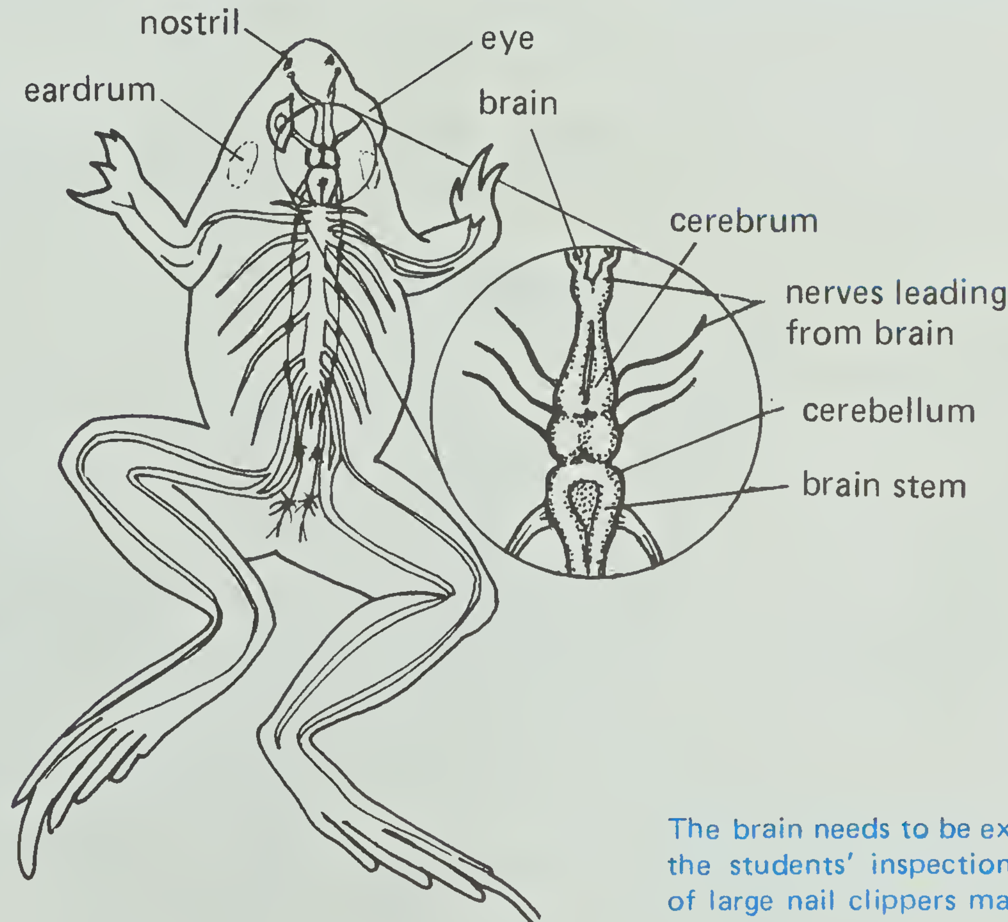


● 16-8. In what directions do nerves lead away from the spinal cord?

16-8. Downward and to both sides

B. Remove the pins from the frog, and turn it over.

C. Use this diagram to locate the eyes, nostrils, eardrums, and brain. Then look more closely at the brain. Use the probe to locate the cerebrum, cerebellum, brain stem, and the nerves leading from the brain.



D. Answer Question 16-12 on page 71.

The brain needs to be exposed for the students' inspection. A pair of large nail clippers may serve as a bone cutter.

Part 5: The Human Being

The human nervous system is probably the most centralized and most complex. (Some scientists think, however, that the whale and porpoise may have nervous systems at least as complex. These animals' brains and their abilities to navigate and communicate are still not fully understood.)

The human brain controls many conscious activities and some unconscious ones as well. But the brain is only one part of the human nervous system. The other parts are the spinal cord, nerves, sense organs, and an autonomic system.

Get a human body model — one with a brain. Try to locate the brain, the spinal cord, the nerves leading from the spinal cord, the nerves leading from the brain, and the five sense organs. Then answer Question 16-13 on page 71.

16-9. B, E, D, A, C

☆ **16-9. List the following organisms in order, from the least complex to the most complex nervous system.**

A. Frog
B. Protozoan
C. Human being
D. Grasshopper
E. Hydra

16-10. The human cerebrum is both larger in proportion to body size and more complex. It provides for thinking and planning.

● 16-10. Both the frog brain and the human brain have cerebrums. Which cerebrum is larger in proportion to body size? Which is more complex? What can it do that the simpler brain can't?

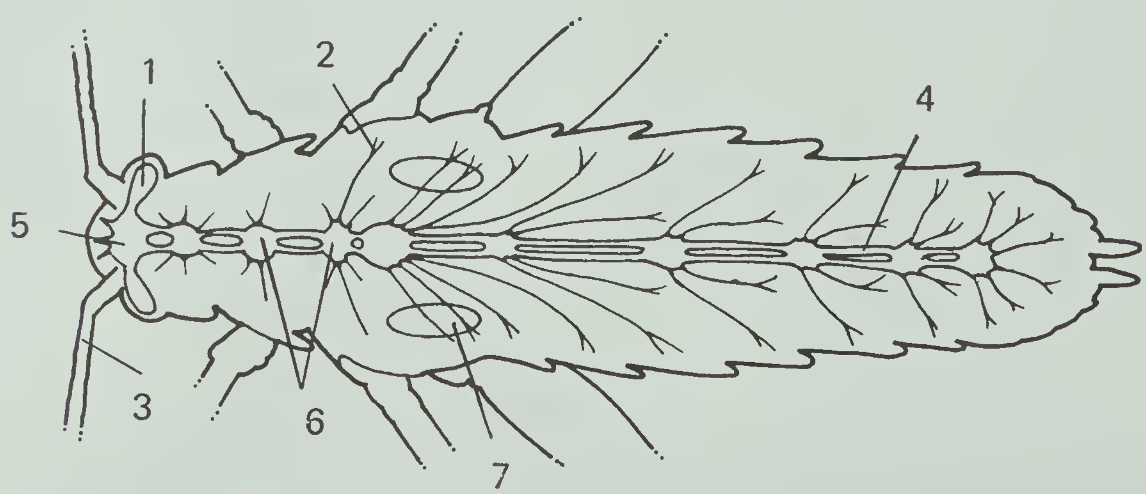
16-11. A5, B4, C2, D1, E3, F7, G6

☆ **16-11. Match the parts of the grasshopper's nervous system with the numbers on the diagram below.**

Parts

A. "Brain"
B. Nerve cord
C. Nerve
D. Eye
E. Antenna
F. Eardrum
G. Ganglia along nerve cord

Grasshopper



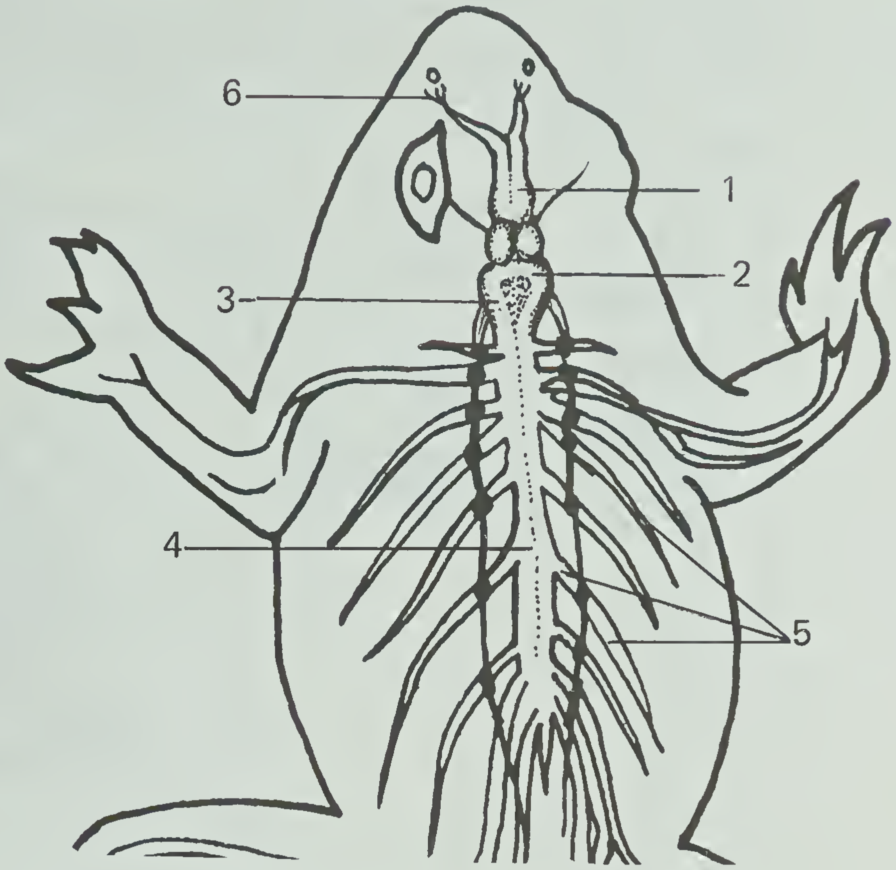
☆ 16-12. Match the parts of the frog's nervous system with the numbers on the diagram below.

16-12. A4, B1, C6, D2, E3, F5

Parts

A. Spinal (nerve) cord
B. Cerebrum of brain
C. Nerves from brain to nose
D. Cerebellum of brain
E. Brain stem
F. Nerves from spinal cord

Frog



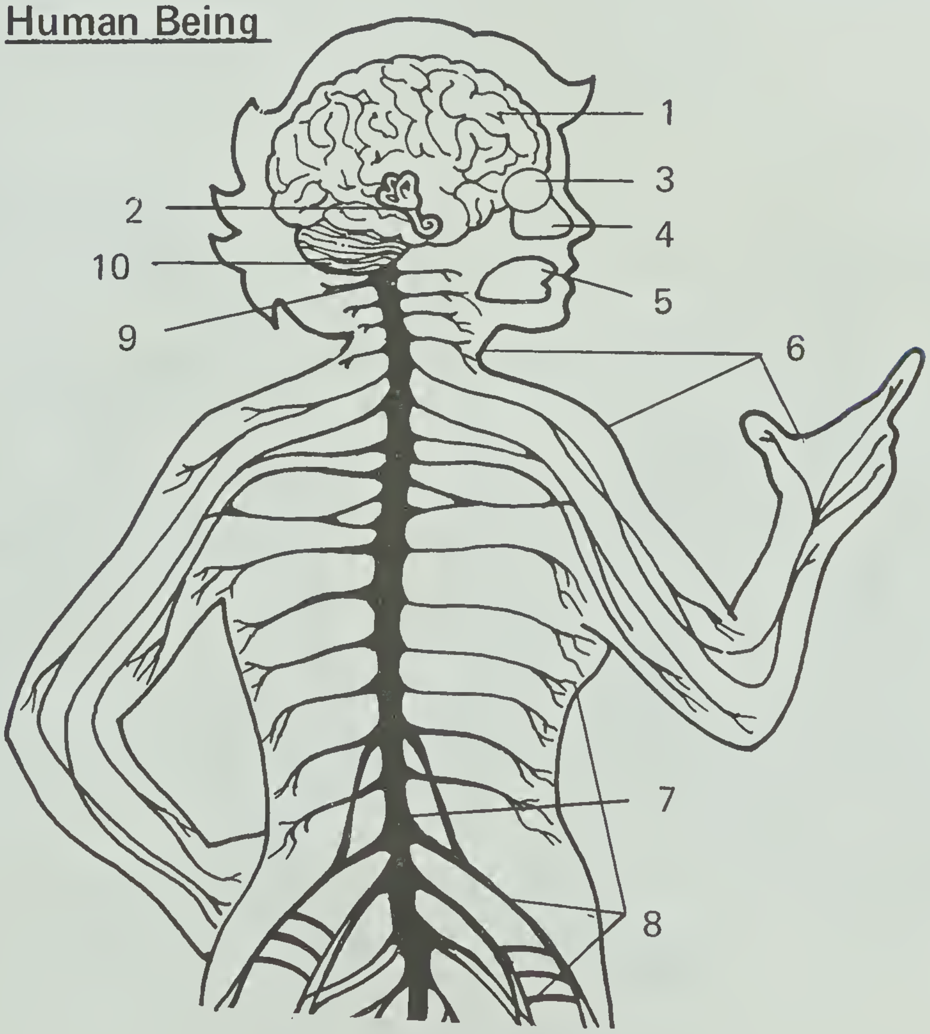
☆ 16-13. Match the parts of the human nervous system with the numbers on the diagram below.

16-13. A2, B10, C7, D5, E8, F6, G4, H3, I9, J1

Parts

A. Ear (internal)
B. Cerebellum
C. Spinal cord
D. Tongue
E. Nerves leading from spinal cord
F. Skin
G. Nose (internal)
H. Eye
I. Brain stem
J. Cerebrum

Human Being

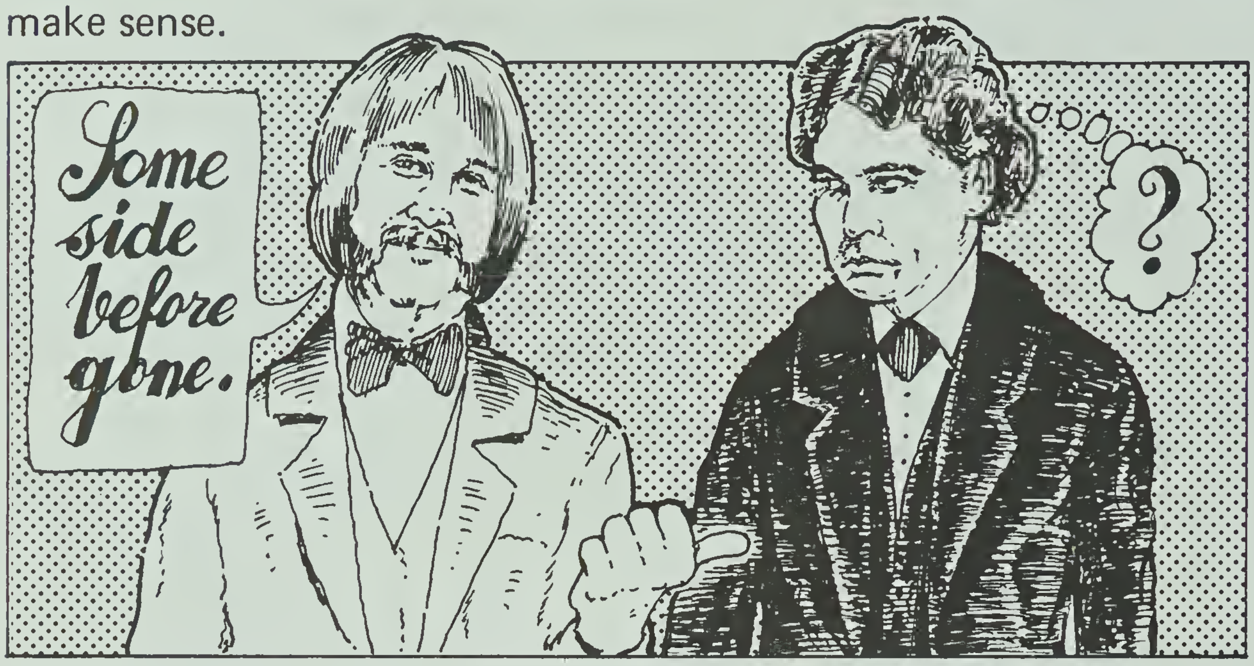


ACTIVITY EMPHASIS: Specific areas of the brain apparently control certain body functions. Many such areas were discovered during electrical probing of the brain.

MATERIALS PER STUDENT LAB GROUP: None

ACTIVITY 17: MAPS OF THE BRAIN

Scientists now know a good deal about what many of the parts of the brain do. A French surgeon named Paul Broca was one of the people who led the way. In the 1860s, he studied several patients who had strange symptoms. They seemed to be able to think, and they could make gestures. But their sentences didn't make sense.



All of these patients either had brain tumors or had suffered some injury to the brain. After they died, Broca studied their brains. He found that the tumor or injury was always in the same region of the brain — near the front. Usually it was on the left side, but for many of the left-handed people, it was on the right side. Figure 17-1 below shows the general location of what is now called *Broca's motor speech area*.

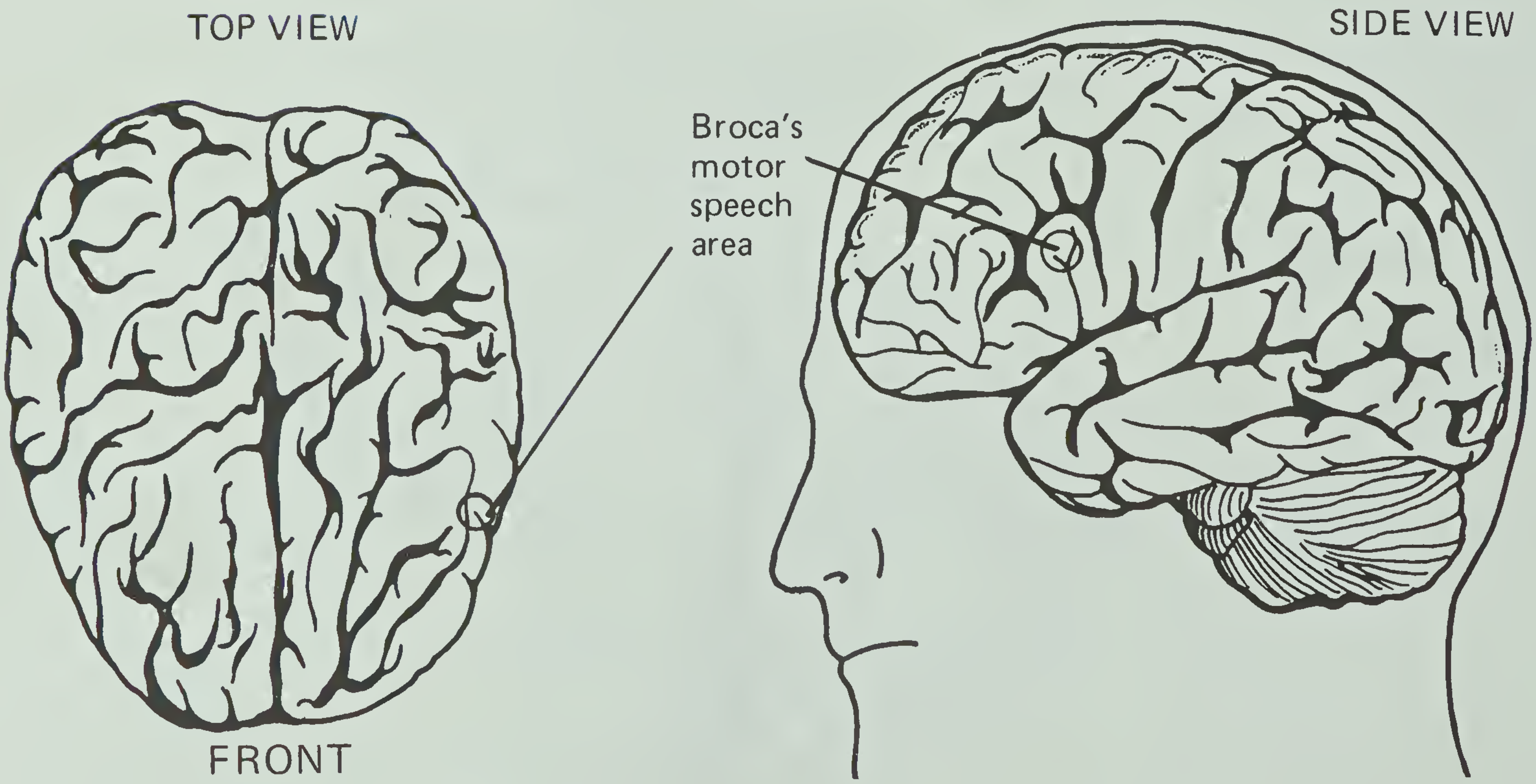


Figure 17-1

● 17-1. Is the person in Figure 17-1 (page 72) more likely to be right-handed or left-handed? Explain your answer.

17-1. Probably right-handed, because Broca's motor speech area is usually located on the left side in right-handed persons

Brain tumors and certain types of brain injury can also produce paralysis, especially if located in the motor areas of the brain. These are the areas that control the muscles. Figure 17-2 below shows a tumor that caused paralysis of the right leg.

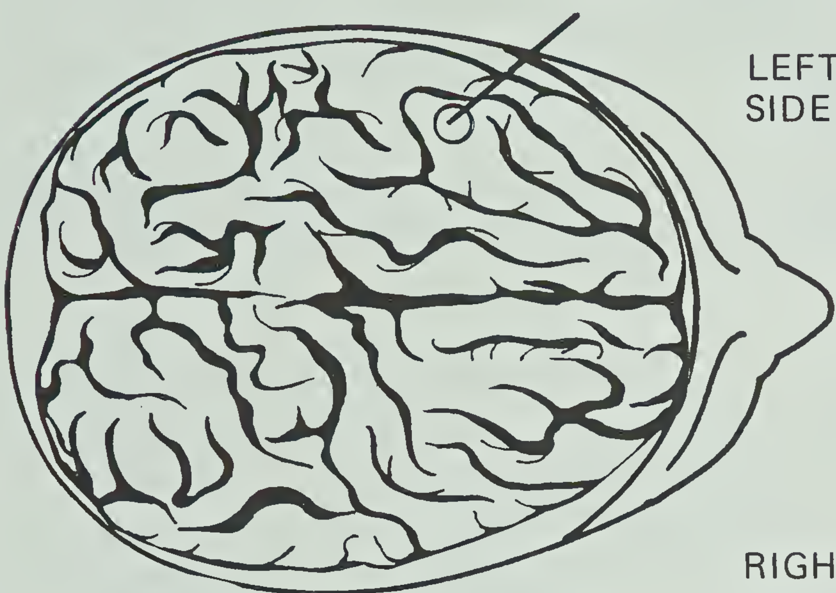


Figure 17-2

● 17-2. Which side of the brain seems to control the motor functions of the right side of the body? The left side of the body?

17-2. The left side of the brain; the right side of the brain

☆ **17-3. How did scientists first find out that certain areas of the brain controlled certain parts of the body?**

17-3. They observed that tumors or injuries to certain areas of the brain affected specific parts of the body.

Recent research on the brain suggests that the left side of the brain is the speech and language part, the right side the imaginative and creative part.

Harvey Cushing, an American surgeon, worked out new methods of studying the brain in the early twentieth century. As Cushing knew, the human brain doesn't sense pain within itself. Only the skin and tissues of the scalp need a light anesthetic. So brain surgery can be performed with the patient awake. Cushing often needed to keep brain-damaged patients awake during surgery so they could help him locate the affected area.

During such surgery, Cushing stimulated certain points in the brain with a small electric shock. He observed the patient's responses. Figure 17-3 (page 74) shows two of these responses.

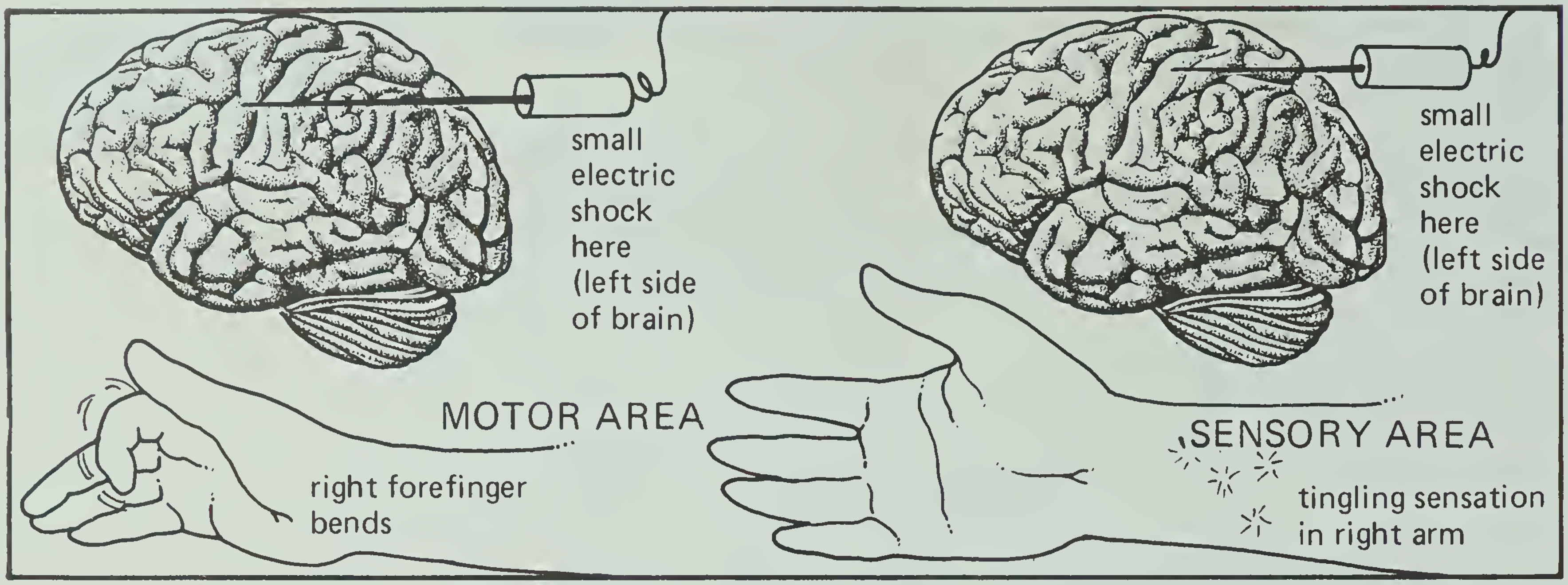


Figure 17-3

17-4. The person feels a tingling sensation in the left hand.

● 17-4. A certain area of the brain controls the sense of touch in the left hand. What happens if that area is stimulated electrically?

Stimulating other areas caused other sensations, such as "seeing" flashing lights or "hearing" noises. By this technique, Cushing discovered some of the sensory areas of the brain — areas that receive messages from the sense organs.

The brain map in Figure 17-4 below shows the motor and sensory areas of the brain. The map is based on the results of the research of Cushing and others. Study the map, and learn the location of each area.

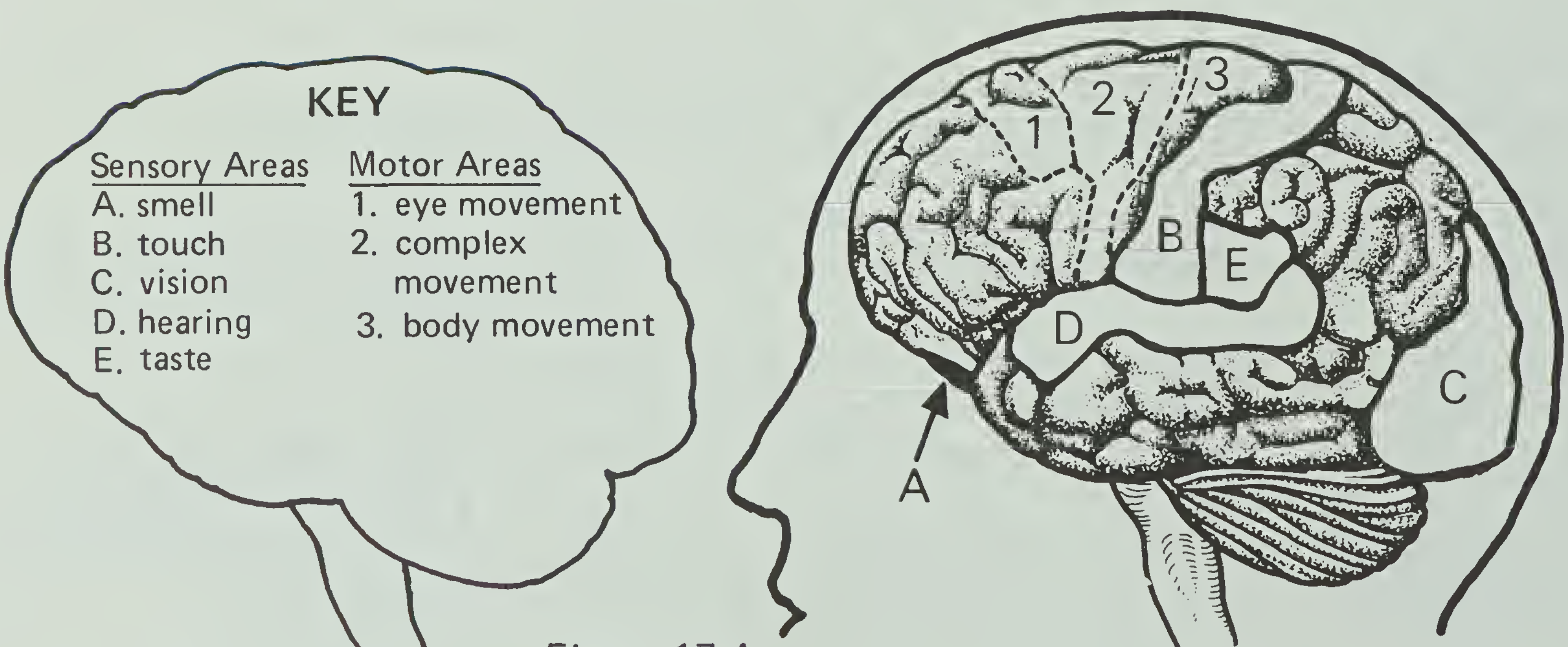


Figure 17-4

17-4. [Answers are listed in the key in Figure 17-4 above.]

☆ **17-5. Cover the key in Figure 17-4 above, and name the sensory and motor areas of the brain.**

☆ 17-6. Suppose a brain-surgery patient was given a small electric shock at each of the five numbered points shown. Without using the brain map in Figure 17-4, tell which point would probably correspond to each of the following responses.

17-6. A2, B5, C1, D3, E4

A. The patient's arm moves.
B. The patient hears a sound.
C. The patient sees light.
D. The patient's eye moves.
E. The patient feels a tingling sensation in the fingers.

Skill at certain movements also involves certain brain areas. For example, when you were learning to tie your shoelaces, you probably had to think about every motion. But, with practice, the motions became a habit. Figure 17-5 below shows how such unconscious habits may develop.

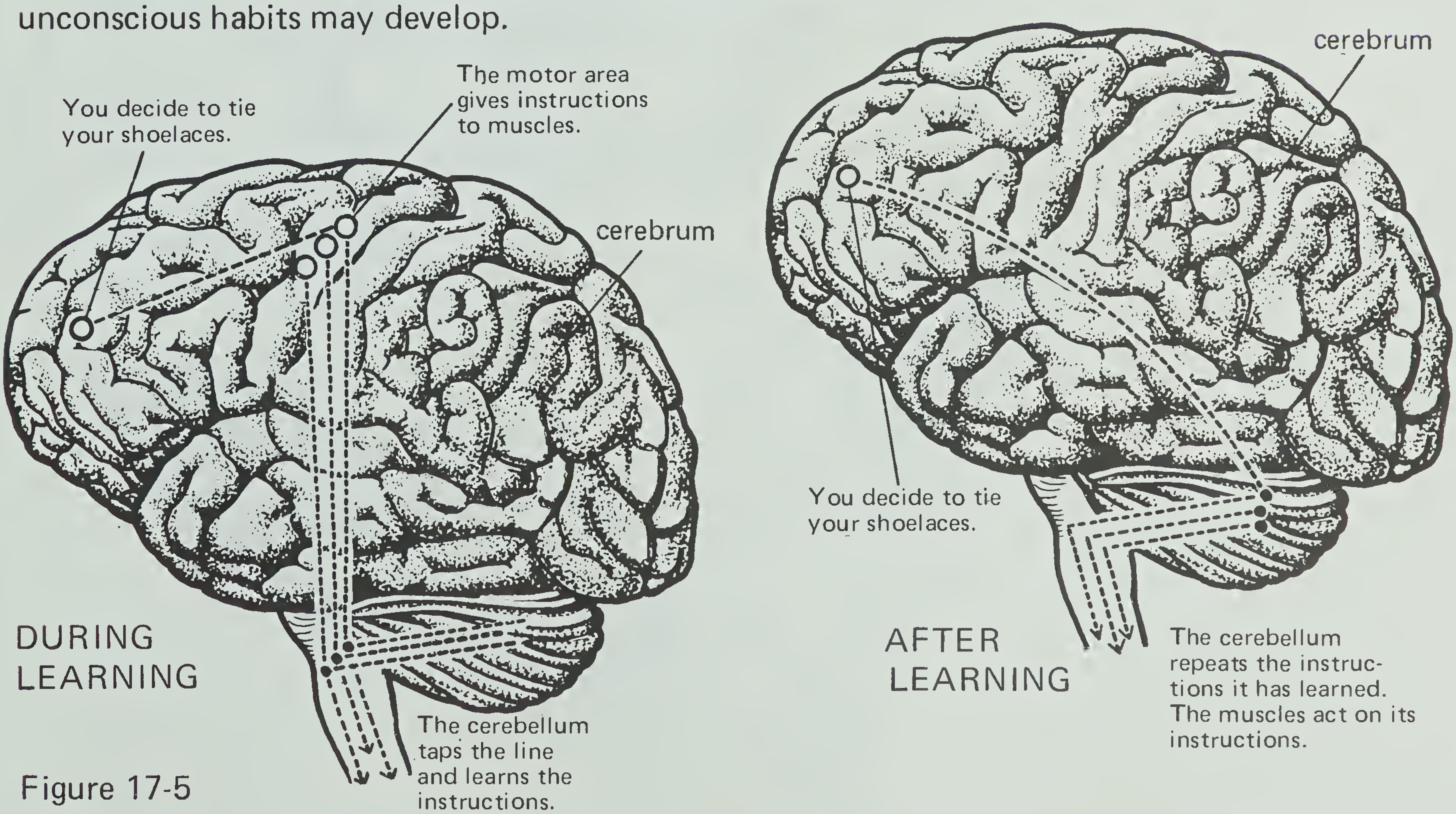


Figure 17-5

17-7. The cerebellum

● 17-7. As a muscular action becomes a habit, which part of the brain may take over its performance?

Not all brain functions are so specifically localized. For example, the front part of the brain is thought to be the main center of memory. But other areas of the cerebrum seem to be involved too. It may be that memories are stored in more than one way. Or there may be a physical difference between long-term and short-term memory. The processes of memory are still something of a mystery.

17-8. Memory

17-9. Surgeons discovered that a mild shock applied to a certain area of the brain produced activity in or sensation from a particular part of the patient's body.

● 17-8. What is one brain function that remains difficult to localize in the brain?

☆ **17-9. Describe how the locations and functions of various sensory and motor areas of the brain were discovered.**

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